CHEMISTRY IN THE WORLD'S WORK

HOWE

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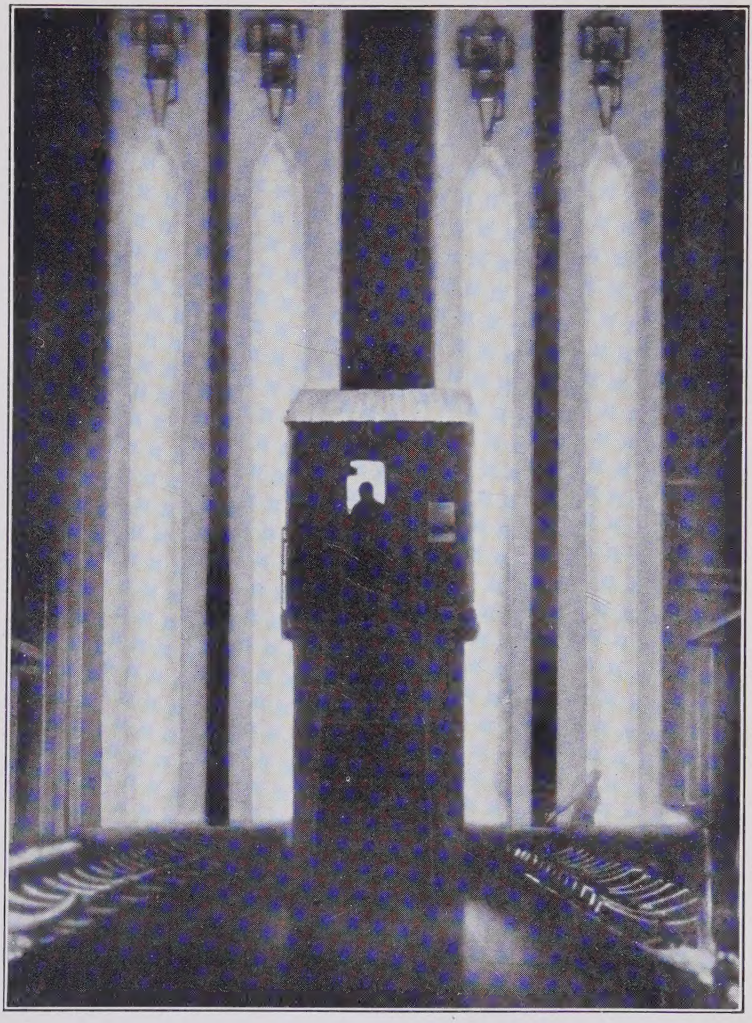

GREAT GLASS CYLINDERS.

Great cylinders of glass made uniform in diameter and thickness of wall by controlling the viscosity of the liquid glass and the air pressure applied are now drawn from pots to replace the less perfect and much smaller cylinders once made by hand manipulation and air blown from human lungs. It is an excellent example of the banishment of hard labor, thanks to scientific contributions. (Courtesy, Pittsburgh Plate Glass Co.)

CHEMISTRY IN THE WORLD'S WORK

BY

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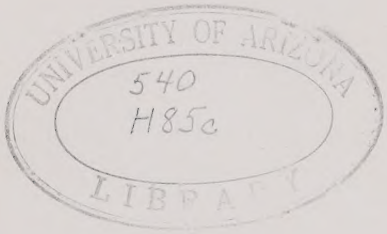

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PREFACE

THE object of this work is to emphasize in language easily understood by those not technically trained, the part which chemistry has played in assisting in the attainment of our present level of civilization. The writer is not unmindful of the fact that chemistry as we have come to know it would be impossible without physics and that physics in turn could not have reached its present development without mathematics. There is also that great field of activity commonly called engineering which is to a large degree applied science and therefore has in it much of applied chemistry as well as of other natural sciences. This is only another way of saying that to-day the ease with which the dependence of civilization can be shown to rest on a particular field of human activity only emphasizes the interdependence of these activities rather than the dominant position of any one of them.

However, chemistry, physics, and mathematics are so fundamental that if any of the natural sciences can be given a place in the first rank, it must be these three, and of course the chemist sincerely feels that if any one deserves the first position, it is the science with which he is most familiar. In this work only a few of the major activities in which chemistry has played a conspicuous part have been set down.

Rather than choose the particular industries to which the science has made notable contributions, it has been thought best to organize the discussion along the lines of those activities which have marked man's progress out of the jungle onto the present plane of living which we designate as modern civilization.

The information has been brought together from numerous sources, to acknowledge all of which would be a practical

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impossibility. Bits of information have been gleaned from all sorts of texts, from public lectures, and from casual conversations with numerous scientists. Having in mind that the book will be read by those not especially interested in extensive detail, many points have not been fully developed, but have been included as much to stimulate thought and inquiry as to give information. If this work serves in any way to win a wider circle of friends to the work of the chemist and to secure for him a fuller appreciation and more substantial support on the part of the public, it will have served its purpose.

H. E. Howe

Washington, D.C.
June 1, 1926

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Chemistry in the World's Work

Chapter I

SOLITUDE

A few moments alone are frequently an appreciated advantage, but continued isolation attracts no one. Solitary confinement is recognized as a method of punishment, and we once knew a man who conceived the tortures of the unrighteous in the hereafter to consist of banishment to eternal solitude. The necessity of being alone much of the time constitutes one of the handicaps of service on lightships and lighthouses, not to mention sheep herding, and many other land activities. History is filled with tragedy developed from extreme loneliness, and in our day the institutions for the insane derive a fair proportion of their inmates from isolated places. The diary of a country girl written in 1865 reflects vividly the influence of the monotony which surrounded even the well-to-do but lonely farmhouse of that day.

That was in 1865. What of to-day? We are benefiting from the scientific work of a century and in ten years have made more apparent progress than in the previous ten — yes twenty — centuries. There are still places where communication is established only by imitating the marathon, the signal fire of the Indian, or the pony express, but when those methods were devised, no better ways were known. To-day we often know better than our performance would indicate.

Isolation may be classified as physical and mental, both of which are being reduced to a minimum. In '49, ten miles a day was good progress across our continent. To-day the only monuments to ten miles an hour are the district speed limit signs which the constable has not been energetic enough to remove.

We no longer brag about the horse that could do six miles an hour more or less continuously and boast instead of our sixty miles an hour six-cylinder motor. When I used to visit farms in the interests of a beet sugar industry, the horse I drove could make an average of forty miles a day. It was a good horse. Last month a friend casually spoke of driving four hundred miles, between daylight and darkness, as an event of common occurrence.

Some hold that in thus knitting the world into a smaller community science has done the race no favor. This is because men have not developed as fast as science and have not learned how to live more closely together, to be sympathetic with those who do things in a different way, although learning to appreciate their trials and successes. That we must learn these things is obvious, for modern communication and transportation, whatever their disadvantages, have surrounded us with benefits which will not be willingly surrendered. If through these agencies there is an opportunity for misuse of accompanying power, there is an equal chance to use these fruits of science for the good of the race.

Chemistry has made substantial contributions to the effort to break the bonds imposed by solitude. Transportation and communication as we know them to-day have well nigh completely accomplished the purpose. We need go back no further in history than the advent of the railroad to find a few outstanding accomplishments in the field of transportation. The railroad itself is a creature of scientific work, for the materials of construction depend upon research, which has taught us how to fashion materials which will stand the stress and strain incident to such highly specialized service. A relatively small percentage of our iron is found as native metal. Most of it is in the form of the oxide or rust and with this there are found in the ore other chemical elements and compounds which make necessary chemical processes carried out on an enormous scale in blast furnaces. Many of the steps in the operation of the blast furnace have been determined by the empirical method of trial and er-

ror; but Andrew Carnegie, in his biography, states that he secured one of his important early advantages with the help of a chemist who showed him how to make better iron and steel than his competitors from ores less expensive than those used by them. The ores were less expensive because they contained traces, if indeed not appreciable quantities, of elements and compounds which interfered with the usual iron and steel processes. When the chemist and engineer devised a method for controlling the percentage of carbon mixed with iron, the steel era began. We passed rapidly from the iron age to the steel age and at present are passing into the age of alloys. Gayley devised the dry air blast and, as a result, millions of dollars are saved annually in the smelting and the making of steel. The Bessemer process of steel making, in which the carbon is burned out of the mixture by blowing air through the molten metal, remained the most important factor in steel making for many years; but at present the open-hearth process produces most of the steel with the electric furnace gaining in popularity. Extensive experiments have been conducted with steel alloys for the production of rails and certain parts of rolling stock, it having been found in the laboratory that mere traces of such things as silicon, manganese, vanadium, chromium, molybdenum, nickel, copper, and tungsten materially alter the physical characteristics of the steel. While the physical properties are the ones best known, and we speak of steel as having a certain ultimate strength, elastic limit, and other recognized constants, nevertheless it is the chemical composition of the metal upon which these physical properties rest.

It is not an easy matter to obtain a really homogeneous metal. We are finding that gases are occluded at times and give rise to certain defects. A cavity in a billet of steel becomes a "pipe" when the rail is rolled, and this long tube filled with gas within the rail may cause its ultimate failure. The metallurgist, armed with his microscope and photomicrographic apparatus, has learned much of the influence upon strength of the crystal structure of the metal and as a corollary contributes to

the evolution of processes whereby the size, growth, and interlocking arrangement of these crystals may be controlled. The physicist has provided the X-rays for testing purposes and with metals of medium thickness this device offers a means of detecting imperfections. More recently the magnetic properties have been utilized as a means of discovering flaws. Steel has become a dominant factor in our industrial life, and the demand for it is one index to business conditions. Successful steel making depends upon the laboratory and in commenting upon the great work of Hadfield, in England, it has been said that he made his plant an annex to the laboratory in contrast with less successful firms where the laboratory is considered a mere appendage to the more serious business in hand. The influence of chemistry upon the work of the world may be well illustrated by its vital position in relation to iron and steel.

If we examine a modern railway coach, we find it resting upon wheels, in the development of which the manufacturers called in the chemical laboratory. There has been notable progress in the production of car wheels. They are called upon to render severe and exacting service. Besides developing a number of special metals for car wheels it was natural that various makers should have their own designs; but by and by the manufacturers of car wheels entered into an association having for its purpose the advancement of knowledge of the manufacture and the service of wheels. The information has been gathered and distributed on these points, and as a result of such coöperation, one hundred seventy-five patterns have been reduced to four, while the quality of wheels has been steadily improved.

The finishing of railway cars would seem to be a simple matter of paint and varnish; but as a matter of fact it offers problems materially different from those encountered in house painting. The railway car is almost continuously exposed to dirt and foreign substances which make frequent washing necessary if the equipment is to appear attractive. The types of soap or other detergents used for such work more often than

not contain varying amounts of excess alkali, which in time leaves its impression on the painted surface. Even more serious is the abrasion which the coated surface must withstand. This is due to particles of dust in the air which sweep past the coach as it travels onward, to cinders and other large pieces thrown against the car as it travels, and to encountering many minor objects in the course of its service. Up to date railways, therefore, purchase their paints on strict chemical specifications, sometimes have paints made for them, or, in exceptional instances, have operated their own paint factories. With the progress of chemical research has come a new type of coating lacquer first employed on automobiles and at present in the experimental stage as a protective coating for railway equipment. This is a nitrocellulose lacquer made with butyl alcohol, a new solvent, which is capable of holding a sufficient quantity of nitrocellulose in solution to give satisfactory covering power and yet not too viscous to be applied with a compressed air spray gun. It dries too quickly to permit brushing.

We also meet chemistry in the roadbed of the railway. A vast number of ties are required to hold the rails in place, and while extensive experiments have been conducted with steel, with concrete alone, and concrete in combination with blocks of wood, so far nothing has been found which serves the purpose quite so well as the hard wood tie. The conditions under which they are placed makes rotting from the attacks of fungus a natural consequence, for they are embedded in the soil. When ties were cheap their length of life seemed unimportant; but to-day tie replacement is a fairly staggering item in the budget of a standard railway. The chemist is asked to treat the tie to prolong its life, and this he has done with creosote, with zinc chloride, and perhaps soon he will be using toxic substances of the same sort as those found sufficient in protecting marine structures against the marine borer. To secure deep penetration some processes require first applying vacuum to withdraw the air and moisture from the wood cells, and then, after the introduction of the treating solution, pres-

sure is applied so that within a comparatively short time the impregnated layer has assumed considerable proportions.

Chemistry has also contributed to the safety of transportation. The materials supplying the light in the lighthouses are made under chemical control. The powerful lenses also come from the chemist's workshop, and the small gas buoys are his product. An interesting example is the red lens universally used as a danger signal on railways. Before the chemist had shown how to make a glass which is called spectroscopic red, the lenses having a red appearance did not always transmit a red light. By the use of selenium and some other materials it was shown that a glass could be made which would always transmit red light even when submitted to a severe spectroscopic test. Previously there had been cases where engineers undergoing a periodic test for color blindness might, due to some imperfection of the sight, see from the same lens red and green alternately, depending upon the distance they chanced to be from the light. With a spectroscopic red lens, we may be sure that red light will be transmitted, and if any other color is reported to be seen, we may be sure the fault lies wholly with the observer and not with the lens.

The whole under structure of a railway car offers a testimonial to problems solved in the strength of materials, in lubrication, and in automatic safety devices. The part of the car with which we are more familiar, the interior, may have for its flooring a chemical compound known as magnesite. This is made by mixing in proper proportions magnesium oxide and magnesium chloride so proportioned that in the finished product neither shall remain uncombined with the other but unite to produce magnesium oxychloride. This is also known as Sorel cement and offers a number of advantages such as insulating properties, resistance to wear, capability of being colored, of being troweled into place and quick setting, all of which make it desirable for such application. The seats of the car are liable to be upholstered in some form of artificial leather made by treating a cotton fabric with a solution of cotton

known as nitrocellulose and pressed or printed with a design to give an imitation of the kind of leather required by the surroundings. The ease with which such material can be cleaned, the difficulty with which it absorbs foreign materials, the wear which it is capable of giving, all indicate it as desirable for such purposes. The paint and varnish with which the car is finished are made under chemical control and may even be prepared from scientific gums, the duplicates of which are not to be found in nature but which possess characteristics more desirable than the natural products. Lacquers and varnishes made from such scientific gums and resins are more constant in quality, make possible a wider variety of surfaces, and with the growing demand for such materials, are produced at a price not possible with natural products. The glass of the windows is another chemical contribution, while many of the lighting systems owe their origin to the work of the chemist. There are many cars still lighted by a gas known as Pintsch gas carried compressed in cylinders. This was preceded by kerosene and has been succeeded by electric light systems cleverly devised to operate with storage batteries when the train is standing still or moving slowly, but supplied by a generator direct when the train exceeds a certain predetermined rate. The same principle is now employed in the automobile.

Railroad tunnels are driven with facility, thanks to chemical compounds which we know as explosives. It is interesting to note that a tunnel constructed as part of an aqueduct system of ancient Rome required in building the labor of eleven thousand men for two years. With explosives and modern machinery the same tunnel could be driven to-day by one hundred men in ten months. After driving these tunnels, they are often protected with a lining of cement, another chemical product, applied under air pressure with the modern cement gun. The same device is used to protect iron work in the service of railways, while concrete has made possible improvements in bridge construction, in the erection of terminals, and in the maintenance of rights of way to an astounding degree.

This list of examples of applied chemistry could be expanded indefinitely; but the important thing is that, whether it is the construction of the roadway itself or the building of equipment or the operation of the train, the contributions of chemistry are of major importance. Such modern transportation has made the world one big market. Modern transportation has enriched the life of the farmer or the dweller in rural communities by making available to him as complete a line of necessities and luxuries as may be enjoyed by his city cousin. We knew a grandfather, who, in his early married life, carried his sugar, salt, tea, and coffee from a little fort on Lake Huron forty miles away through the woods to a clearing where he was establishing his home. To-day, the farmer in that community may enjoy his Florida grapefruit, his California oranges, his Rocky Ford melon, and his Turkish cigarettes with the same facility as any one else.

What the steam railway has accomplished in making isolation a thing of the past the electric railway has expanded, for it has presented a service most welcome to thousands. It is but one of those benefits derived from the electrical industry which has been expanded at a marvelous rate in the United States. Such an expansion would have been impossible without large investments in fundamental research and the application of mathematics, physics, and chemistry to a host of problems, the mere listing of which would more than fill these pages.

Electrical devices, for example, depend to a considerable degree upon pure copper and upon homogeneous carbon or graphite. While much copper is found as such, there are nice refining problems in producing a pure article. The electrochemist has made pure copper commercially possible. The Bessemerized matte, which is an impure metallic mass containing sulfur resulting from a smelting of copper ores, may contain copper sulfide, copper oxide, gold, silver, platinum, iron, nickel, cobalt, arsenic and its oxides, antimony and its oxides, selenium, tellurium, bismuth, and bismuth oxide. The electrical industry wants a copper 99.9% pure. This matte is first refined in a fur-

nace and then cast into anodes. The electrolytic bath consists of copper sulfate in a solution acidified with sulfuric acid. Direct current is employed with a sheet of pure copper as the cathode. When the current is applied the copper sulfide and copper oxide are precipitated and slowly dissolve. The same thing happens to the arsenic and its oxides or it may remain unchanged in the presence of sulfuric acid. Antimony and its salts either dissolve or form an insoluble salt, while bismuth dissolves or precipitates out. The gold, silver, platinum, selenium, and tellurium are precipitated as slime at the bottom of the tank from which they are later recovered as by-products. The iron, nickel, and cobalt do not plate out at the cathode, and as a result of this, there is built up at the cathode with the copper from the impure anode a product more than 99.9% pure.

To the electrochemist, also, we are indebted for artificial graphite. Much graphite is mined from natural deposits; but it is difficult to find homogeneous pieces from which some of the large parts required for modern electrical apparatus can be fashioned. Large amounts of pure graphite are now manufactured by Acheson's process. This consists in heating coke with iron oxide or sand and some pitch in an electric furnace of the resistance type. These furnaces hold three or more tons and the operation is completed in from twenty-four to thirty hours. Graphite ground with coal tar or low grade molasses may be moulded into the desired sizes and shapes and when baked in the electric furnace is ready for use.

Chemistry has also played an important part in the perfection of insulation. This ranges from elaborate glass, porcelain, and other ceramic insulators, which make safe the erection of high tension lines across the country, to special paper used in the case of extremely fine wires in telephone cable and special instruments. Rubber, pitch and other types of organic materials have been largely drawn upon as raw materials for insulation, and the point at which these materials and insulating varnishes break down is the limiting factor in the construction of much electrical equipment. When the ladies first adopted

the tight skirt, street cars were redesigned to eliminate the steps. This required a complete change in the design of the motor such that the chemists were called upon to produce a new form of insulation for certain parts of the equipment. Thus, even fashion made it necessary to call upon the chemical laboratory.

In these days both the railway and the electric line find a strong competitor in a new-comer. Gasoline is rapidly changing the complexion of our transportation problem. The use of the internal combustion motor has not only extended the radius of millions of people one hundred fold, but enables many to do their work in less time, giving leisure, the proper employment of which constitutes a new problem in our economic and social life. More than that, by doing in the tropics the type of work performed by the domesticated horse and ox in enabling man to develop the natural resources of the temperate zone, it may change the character of our agriculture and open up new sources of raw materials as well as new markets. Gasoline has quickened farm activity and brought with it such other advantages as good roads and schools, the ability to meet frequently with those interested in the same activities, whether these be church, lodge, or politics, and may ultimately serve to attract back to the land thousands who have left the farms because they felt isolated. The log schoolhouse which the last generation attended served a relatively small number, for it could only accommodate those within a radius measured by the length of the legs of the smallest children, as Doctor Slosson has said. In our time we have seen the log schoolhouse and its successor, the little red schoolhouse, replaced by the township school, presided over by better teachers and served by the motor bus calling for the children and returning them to their homes quickly and safely, regardless of weather.

Gasoline is derived for the most part from crude petroleum. In addition, many millions of gallons are now saved from casing-head gasoline and from that type of natural gas which bears gasoline vapors. To maintain an adequate supply of liquid

fuels satisfactory for use in internal combustion motors presents one of the important scientific and commercial problems of the day. In the beginning of the industry the simple distillation of the crude petroleum in which the gasoline and other low boiling-point fractions were simply driven off and collected in a condenser gave adequate supplies but that time has long since passed. If we had continued to depend upon that source of gasoline, there could have been no such expansion of the motor business as we find to-day. The chemists, however, found that by applying high temperatures and pressures, the higher boiling-point fractions, the large complex molecules of the petroleum, could be broken down into gasoline bodies, and so there was begun the development of methods which ever strive to convert a larger and larger proportion of petroleum into motor gasoline. Twenty, forty, and sixty per cent conversions have been achieved and much higher figures are claimed for some processes.

Casinghead gas is that which accumulates in the petroleum wells and at one time was allowed to waste. This is now condensed, blended, and made available by the hundreds of millions of gallons. Then a chemist found that one essential difference between natural gases was the percentage of wet gas later identified as something recoverable as gasoline. These vapors are collected in oil from which the gasoline is distilled or, since our war-time defense against poisonous gases has taught us so much of activated charcoal, this form of carbon is used as an absorbent for these gasoline vapors.

The automobile and the internal combustion motor used in industry have fastened themselves so firmly upon our civilization that great efforts will be made to maintain them. Petroleum resources began to be formed millions of years ago, and we know of no method whereby they will be maintained or replenished when they become exhausted. So, while a group of engineers and physicists strive to increase the efficiency of the motor which now gives in the form of power scarcely more than 5% of the energy in the gasoline, the chemists and chemical engineers bend their efforts toward increasing the quantity of gasoline ob-

tained from petroleum, the development of new sources such as shale oil, and the investigation of possible supplementary fuels. What is much desired is a source of motor fuel depending upon some reproducible raw material. We would like to grow our fuel annually just as we grow our food crops. The only material so far produced commercially in this fashion is alcohol from the fermentation of sugars and starches occurring in sugar cane, potatoes, and similar materials, all of which, unfortunately from the economic standpoint, have high food values. Much alcohol has been made from waste cellulose such as wood waste by first converting the cellulose into a fermentable sugar by an acid process and then fermenting the sugar with a strain of yeast particularly developed for the purpose. This is a possibility but not economical at the present price of petroleum or alcohol produced by other methods. It costs too much to collect wood sufficient for an economic size unit.

Alcohol, as it is commonly known, contains 5% of moisture and its presence prevents the perfect mixing of alcohol with gasoline. Other materials must be added to perfect the blend. Alcohol has been produced for a long time in the dehydrated or absolute state, which is 100% alcohol. This has always been expensive, say, five dollars a gallon without the tax added, for it was distilled over sodium in elaborate apparatus which insured the absence of moisture in the final product. Within a few years a commercial method, the full details of which have not been disclosed, has been perfected whereby one company can produce twenty-five hundred gallons daily of an absolute alcohol in a semi-commercial apparatus. This material mixes in all proportions with gasoline, and when used in the ratio of 80% gasoline and 20% dehydrated alcohol, gives an excellent mixture for the internal combustion motor.

Within the year a development of the greatest importance both for the future and the present has been announced. This is the synthesis of methanol or wood alcohol, as it used to be called, from the gases carbon monoxide and hydrogen. Heretofore, all such alcohol has been derived from the destructive dis-

tillation of hard wood without access of air. This yielded among the products charcoal, pyroligneous acid, acetate of lime, and acetone. Whether these or the wood alcohol should be termed the by-product depends upon the demand and the market conditions. This industry required the cutting of hard wood a year in advance, that it might season, and notwithstanding improvements in distillation and refining processes, the methanol carried impurities which gave it a characteristic odor. Whether we shall continue in future to obtain our methanol from the forests of the present or from the forests of the past is largely an economic question. It is important, however, to note that the synthetic process is already on a commercial basis abroad, that it is reported costs have been realized less than 20% of those possible with the distillation of wood, and that the pure product has been imported into America at the rate of thousands of gallons at a retail price threatening the wood distillation industry. Carbon monoxide and hydrogen, the raw materials for the synthetic process, may be produced from a wide variety of combustible materials. At present they are made from "brown" or bituminous coal, of which the world is known to have an exceedingly large store. While methanol, as such, may not be used in the near future as a motor fuel, it is already known that certain changes in the proportion of gases used together with slight differences in temperatures, pressures, and catalysts enable a petroleum-like body to be formed. Such chemical developments, therefore, may easily hold the key to the future, so far as the internal combustion motor is concerned.

The characteristics of gasoline type engines are such that greatly increased efficiencies cannot be had with our present fuels without detonations which give what is called knocking. Engineers have estimated that if this knocking could be eliminated, changes in motor design involving the use of higher compression could be made with a saving of at least 20% of our gasoline. Extensive researches have shown a number of compounds that reduce or eliminate knocking. The most efficient so far discovered is a compound, tetraethyl lead. Exceedingly

small quantities of this material eliminate knocking. If dissolved with an organic salt of bromine, the lead does not remain in the engine to form an annoying oxide, but is discharged from the cylinders as the oxide mixed with carbonate, sulfate, etc.

A limitation to the preparation of this economically important material is the world supply of bromine. This would be quite insufficient if such an anti-knock compound were used in all the gasoline sold in the United States. The world has been searched for new sources of bromine, the most promising of which from the standpoint of richness is the Dead Sea. There are many difficulties of climate, politics, and transportation to make the Dead Sea an unattractive place for work. One of the great chemical companies, therefore, undertook to win from the sea the seven-thousandths of one per cent of bromine which its waters contain. A successful process has been developed for this purpose, and since large quantities of water were to be handled, the initial experimental plant was installed on board a ship. The ship cost less than a parcel of land that might be required for the plant, could go where an uncontaminated source of seawater was available, and had no waste disposal problems to annoy it. By placing the pumps and most of the machinery below the water line on the boat the power required for pumping was minimized. In the trial run the plant met expectations and produced an organic salt of bromine which could be used directly in the anti-knock compound. Tetraethyl lead was voluntarily withdrawn from the market, awaiting an investigation under the auspices of the Surgeon General of the United States, who sought to determine with the help of a committee of experts whether the retail distribution and widespread use of this compound of lead constitutes a real menace to the public health. Based on the recommendations of the committee, regulations have been devised under which the material may again become available.

The lubricating oils, the greases, the waxes, and special compositions for heavy duty as lubricants are all products of the chemist. An interesting speculation is whether we shall be able

in future properly to lubricate our power plants, if we insist upon burning up our sources of petroleum as rapidly as may be. For some services no suitable substitute has ever been found for the lubricating oils prepared from petroleum. The animal and vegetable oils are wont to saponify or emulsify under conditions which do not affect these petroleum base oils. The use of lignum vitæ, an exceedingly hard, dense wood, as a bearing for one of the huge hydroelectric generators at Niagara Falls would indicate that for such important service a way may be found for at least greatly reducing the amount of oil required if, indeed, the thin film employed really needs to be replaced. Unless something of this sort can be devised, huge hydroelectric power plants regarded as conservers of our coal as a source of power might lie idle for want of lubricants. The chemist somehow has a firm belief based upon his experiences that he will be permitted to discover new ways of obtaining needed materials when the real need approaches. Methanol, for example, might not be produced indefinitely from hard woods, for beech and maple have been used faster than they have been growing. Even while considering reforestation, the laboratory has developed a synthetic process depending upon raw materials now available in abundance.

The automobile itself is a creature of chemistry. The hardened working parts of the engine are made so by chemical processes. The chemists helped to make the tires resistant to the wear and tear of the road. The upholstery, the finish — every part has a chemical history. A few years ago one of the scientific societies exhibited a chassis, to each part of which was attached a ribbon leading to a placard which stated to what extent chemistry had played a part in developing that particular unit. As you may have suspected, no part of the car escaped untagged. The ability to produce alloys of iron with some of the rare metals like vanadium has contributed directly to the savings, the pleasure, and the industry of literally millions of people. Many parts in one of the popular price cars would cost three or four times their present price but for the fact that

vanadium steel possesses the requisite strength and at the same time may be readily machined. The same parts could be made of high carbon steels and have the strength demanded; but these steels could not be machined. They would have to be ground to dimensions, and this extra labor would remove the car from the price level which has meant so much to its popularity.

There have not been many years since the motorist ventured forth with fear and trembling, not knowing just when a tire would fail and regardless of circumstances he would be called upon laboriously to repair or replace it. The service of tires has been increased many fold because chemists have learned more of the chemistry of rubber and have ascertained to some extent, at least, the relation of certain mixtures and compositions to serviceable wear. It is well known that, in addition to rubber, tires must contain certain other components and fillers, if they are to withstand the great punishment which the average car gives them. Those interested in the ways of matter and appreciating some of the factors involved, marvel at the abandon with which the average motorist drives his car over all sorts of roads under all kinds of conditions and confidently expects that nothing will happen. Zinc oxide and carbon black, made by the burning of natural gas or from acetylene, itself a chemical product, are among the principal fillers, though much clay is used in some types of rubber goods. We have learned how to employ long staple cotton and are beginning to become acquainted with rubber latex itself which may afford a new and beneficial raw material for tire manufacture.

It was only a short time ago that a chemist discovered that rubber latex, which is the sap of the rubber tree, contains a protein which under the old conditions began to decompose shortly after it was taken from the tree and, in a mass of rubber collected by natives, accounted for such a lack of homogeneity as to influence the quality of the cured rubber. This chemist also found after experiment that ammonia is an excellent preservative for this protein; so now ships bring latex preserved in ammonia to our shores where it is dried by a spray process, giving a new

rubber. Also it may be used as a cement, to impregnate cloth and cords, to form coatings and to be experimented with as a new material in this field.

The brake-lining, a most important part of the motor car, owes its efficiency to asbestos fiber, that remarkable, natural, heat resisting product which with fine wire is woven into fabric called upon to perform very exacting duty as a brakeband.

But this is not all. The motor car to be popular must have a satisfactory highway and here again we beseech chemistry for help. The cement for the concrete is produced under chemical control, and in accordance with chemical reactions, from clay or shale with limestone or marl. The finished product must contain silica, lime, and alumina in the right proportions and must be free from excessive amounts of iron oxide, magnesium, potash, and soda. Slate waste, slag, shale, and alkali are sometimes used. There are natural cement rocks such as those found in Pennsylvania. The size and type of aggregate that can be used with cement to form the best concrete have been determined by scientific means, as has been the mechanism of setting and curing, so that maximum strength may be developed in the minimum time. Asphalts, both natural and those resulting from the distillation of petroleum, tar and tar oils, all are either under the control of the chemist when applied to highways or are by-products of chemical industries. There still remains a number of highway problems. It is desirable to construct a highway that will still be useful before the bonds issued for their building have been retired; but we must know more of proper design and construction, if this happy state is to be widely realized.

What of the next step in transportation? Is there a landing field in your town? Have your city fathers taken steps to preserve a tract of suitable topography, say, a half mile wide by two miles long, which will serve commercial aviation? Until we have developed new types of planes and dirigibles, such large areas are desirable; but, no doubt, one of these days even the farmer will find it advantageous to set aside an

acre or two for his landing field. He may already receive his mail by the aid of this contrivance, and the passage of the airplane overhead no longer excites curiosity.

Like the motor car this newest invention to break isolation owes its existence in large measure to the special materials which the chemist in coöperation with other scientists has provided. There may be noted such important materials as the light weight alloys of great strength. Magnesium, aluminum, and copper have been brought together to perform this service. The shape and balance of the propeller is an essential feature of the airplane, and laminated woods built up with a special waterproof adhesive devised for the purpose have been found best. Not only must the wings be constructed of specially designed fabric, but this fabric must be protected against changes of dimension and weight due to changes in moisture. They are made taut by treatment with solutions of nitrocellulose, in turn coated with cellulose acetate, that they may be less inflammable. The fuels used must be carefully checked. One cannot take chances with the lubrication, and in high altitudes a tank of oxygen may be useful to the aviator and indeed to the engine, which with difficulty secures enough oxygen to maintain combustion at the higher altitudes. The dirigible likewise presents a group of problems essentially chemical. Here again we find the demand for light superstrong alloys. The fabric for the gas bags must not only keep the gas in, but keep the air out, remain flexible and impermeable for a long time, and retain its elasticity.

Because hydrogen, the lightest of all gases and therefore having the greatest lifting power, is highly inflammable and explodes readily under certain conditions with optimum air mixtures, we use helium, a comparatively rare gas fortunately found of late in considerable quantities in certain American natural gas wells. Prior to the World War, helium was a laboratory curiosity, the few cubic feet existing being worth some two thousand dollars each. Under the emergency, research was undertaken which showed that by utilizing certain

natural gas fields and applying the most recent methods for gas separation after reducing the gases to a liquid, the price could be reduced from two thousand dollars a cubic foot to five hundred dollars a thousand cubic feet. This cost has steadily declined until now so low a price as thirty-five dollars a thousand has been realized. Enthusiasts expect even lower costs to be attained. But the cost problem is still more complicated. Under conditions of load, temperature and altitude, dirigibles and balloons are "valved," which means that gas is allowed to escape from the bags, so that changes in weight such as take place with the consumption of gasoline for driving the motors may be compensated by allowing gas to escape. Otherwise the ship will ascend to undesired heights. Hydrogen is made at a price which made valving of no serious consequence. With helium it is a different story; so engineers were called upon to construct very light weight condensers, which would conserve the moisture formed when gasoline is burned. The weight of the water is slightly greater than the weight of the gasoline burned, so that with such condensers the weight of the ship can be maintained as nearly constant as is desired and valving practically eliminated.

Again, no balloon fabric has yet been found through which air will not diffuse, thus diluting the gas and diminishing its lifting power. Pure gas has a considerably greater lifting power than gas mixed with air. Hydrogen, though cheap to make, cannot be purified following contamination due to air leaking into the gas bags. It is therefore changed some fifteen times a year. Helium can be purified at low cost and reused. This constitutes an advantage which greatly offsets any original difference in the first cost of the two gases. Indeed, the net cost of helium under the most modern conditions of operation and purification is no greater than hydrogen.

Transport by water offers problems no less complex than those by land or air. Even the creatures of the deep play their part, barnacles, in particular, proving annoying and the marine borer destructive. To persuade the barnacle to go else-

where metallic poisons such as copper salts are made into special compounds for painting ship bottoms. More recently the peace-time activities of the Chemical Warfare Service have shown that their poisonous compounds, which do not dissolve sufficiently to be dangerous to other sea life, will prevent barnacles from becoming attached to surfaces and accordingly these compounds are also applied. Similarly piling and other units of wood can be protected against the ravages of the teredo or marine borer by impregnation with such poisonous compounds in a vehicle of oil. A short time ago, untreated marine structures in a single harbor were damaged to the extent of nineteen million dollars in a single season by the marine borer, which came into the bay when a drought reduced the flow of a river and thereby allowed an increase in the salinity of the bay water due to the greater penetration inland of the sea. These chemical compounds may be expected to protect such structures when used in future, test pieces three years old justifying great expectations.

A chemist versed in the application of his science could tour a modern ocean liner and tell the chemical history of all its component parts. True, the chemist alone did not fashion them; but chemistry is the science which deals with the properties of matter as they are changed by conditions, and this being fundamental, he can properly claim a share in all industrial activities.

The corrosion caused by sea water calls for the use of corrosion resisting materials in many parts of the ship. The refrigerating systems installed on passenger ships and certain types of freight carriers have their roots in physics and chemistry. So do the safety devices, the modern compass and the signal systems. It is simply another case where several natural sciences have come together to produce in the modern ship a means for quicker, more comfortable, and safer transportation which aids the farthest corners of the world in shaking off isolation.

We have been discussing in a general way some of the factors

which help to banish physical isolation. What has been said may suggest many other instances of similar service rendered by chemistry. We shall now call attention to a few outstanding examples of the banishment of mental isolation.

Chapter II

MENTAL ISOLATION

The historian, Macaulay, is reported to have said that the establishment of communication constitutes one of the greatest, if not the greatest, achievement of the race. Of course, he meant to include the development of speech and all that has been involved in the combination of sounds which make up the spoken word. But quite aside from this all-important feature, there is much to cause wonder in what has been achieved in establishing communication on a basis that banishes mental isolation even though one be out of physical contact with his fellows. Without some touch with the outside world even the family group may find time hanging heavy on its hands and, becoming irritable, all sorts of unpleasant things may arise. The inability to learn the fortune of those in whom we are interested at times becomes torture, and the "widows' walks" on the roofs of the Nantucket houses, in which the families of the captains of whalers lived, remain a mute testimonial of the days when those at home might not know for as much as four years what had happened to the men at sea.

We have come to depend largely for our information on paper and ink, the telephone and the telegraph, and wireless. Much has been written about the origin and development of paper, which, no matter by whom introduced, has in these times become a chemical manufacturing process. In a sense, ours has become a paper civilization. At the time of the Revolutionary War there was very little paper, indeed not enough to wad the guns of the soldiers and scarcely sufficient to carry the orders to the officers. In 1810, the use had increased to only 1 pound per person per year; but by 1850 this had grown to 8 or 9 pounds and, due to the Civil War, increased to 25 pounds per capita in 1869. Fifty-seven pounds

was the annual allotment in 1899, 150 pounds in 1923, and America now consumes paper in excess of the weight of its population annually. A comparison of the paper used in other countries may be interesting. The government reports of 1920 indicate that Russia consumes 13 pounds per person per year, Japan 16, Norway 33, Germany 45, Great Britain 75, and the United States 150.

Generally speaking, paper is made from rags, straw or wood, with such other forms of cellulose as bamboo, cotton linters, and certain grasses supplementing the larger supply of these principal raw materials. Paper can be made to-day by the same methods employed by the ancients; but if all paper were made by this process, there shortly would not be enough to meet even our most pressing needs. While the Chinese made one small sheet at a time by hand, producing not more than 200 fine or 1200 low grade sheets per day, we now have paper machines up to 240 inches in width which continually make 400 linear feet per minute of high grade paper and more than 1,000 feet per minute of the lower grade varieties. Obviously this could not be done but for a change in the characteristics of the fiber by chemical methods and mechanical treatment to give it the strength to withstand this tremendous speed at which it is pulled over and through the machine.

Paper is made by the sulfite, sulfate, or the soda process. In the sulfite process raw materials are cooked under pressure with a solution known as calcium disulfite made from lime and sulfur and carrying a certain quantity of sulfur dioxide gas. Soda pulp results when certain woods are digested with a solution of caustic soda, and the sulfate process is a modification of the soda process, the treating liquor being a mixture of caustic soda and sodium sulfide.

One chemical engineer, coming into a mill noted for its dirty pulp, discovered that the sulfite liquor could be made such that a stronger pulp could be produced, much less fiber destroyed in the process, thereby effecting a great saving, and that the attack of the liquor upon the bark could be minimized, thereby

greatly reducing the number of dirty specks per square foot of pulp. Continuing his work, he has made the mill's product the standard of the world as regards strength, color, and freedom from dirty spots. The pulp as it comes from the digesters would be unattractive unless bleached or dyed, both procedures requiring chemistry. Sulfate pulp is seldom bleached to any extent, for it produces the heavy strong wrapping paper. The other pulps are bleached with chlorine or bleaching powder, colored by the addition of mineral pigments or dyes according to the requirements of the case, and given the desired surface by the use of a size prepared according to chemical formulas calling for rosin, or casein, and if coated or enameled, clay may be used. Much paper is reworked to make lower grades or some type of card, box or wallboard. The ink must first be eliminated and there are several methods for removing it. One of the latest employs a clay known as Bentonite.

Those who insist upon ink as the more important discovery point out that, however useful paper may be, unless ink had been provided with which to form the characters the paper of itself would have had little value and that with ink at hand other mediums than paper could be used as a carrier for the message. However that may be, inks are important, as has been frequently proved in law suits involving altered records, that fraud might be proved, or records faded almost to extinction through time. The early inks were made by means of lampblack with glue to which a preservative was added to prevent decomposition. In China and Japan this type of ink is still in use, and no better inks for the draftsman and the artist have been discovered than carbon inks, which consist of lampblack mixed with fish glue. The permanence of carbon is the important factor in this formula. Another important series of inks contain a compound of tannin with iron and also iron with gallate made from an extract of gall nuts.

The ancients, as well as ourselves, used colored inks, the former obtaining theirs from extracts of plants and pigments, while we use coal tar dyes to give us a wide range of color in

writing fluid. Logwood extract has also been employed as an ink, and the coal tar dyes may sometimes be combined with the iron-gall inks. This combination is useful in preventing fraud, since materials which will bleach the one do not affect the other. Printing inks are to be had in great variety, the chemist being called upon to provide ink to be applied from raised surfaces like type, from flat surfaces such as lithographic stone, and from rollers which typify the printing used in colored Sunday supplements. While the drying of newspaper inks is principally by absorption, the better inks do not depend wholly upon this but contain small amounts of drying oils. The cheaper inks are made of carbon black and lampblack ground in oil and are used on that type of paper which rubs off on your hands and clothing while you read it. The transparency of inks is an important matter to the newspaper and in the printing of colored illustrations where one color is superimposed upon another, but with the underlying color producing an effect by showing through, thus giving a satisfactory blend.

The improvements in printing and particularly in illustration have been gradually but consistently developed, and the majority of readers fail to appreciate what has been done for them. It is true that wonderful illustrations were made with the hand carved wood block; but if that were the only method of illustration to-day, our pages would have to be less attractive or else much more expensive. The steel engraving can be made a beautiful piece of work; but can you imagine holding the five o'clock extra on the press while the steel plate was being engraved? Thanks to chemical discoveries, most of our illustrations now involve the use of photography and etching solutions, electrochemical methods, color filters, special types of photographic plates, a long list of special equipment with which the newspaper type of illustration can be produced in a few minutes, and the exquisite color print made with a number of accurately registered separate colors limited only by the expenditure the customer is willing to make. Newspaper annals have many interesting narratives of the superhuman

efforts of photographers to get to the press in time for the extra edition the photograph of some important event. Apparently this romance is soon to be over, for not only are photographs transmitted to-day by telephone, but even by wireless, and reproduced not only in black and white but in three colors. As described in a bulletin of the Bell Telephone Laboratories, the general scheme of picture transmission is as follows:

Reduced to its simplest terms, the problem of transmitting a picture electrically from one point to another calls for three essential elements: The first is some means for translating the lights and shades of the picture into some characteristic of an electric current; the second is an electrical transmission channel capable of transmitting the characteristic of the electric current faithfully to the required distance; the third is a means for retranslating the electrical signal as received into lights and shades, corresponding in relative values and positions with those of the original picture.

Analyzed for purposes of electrical transmission, a picture consists of a large number of small elements, each of substantially uniform brightness. The transmission of an entire picture necessitates some method of traversing or scanning these elements. The method used is to prepare the picture as a film transparency which is bent into the form of a cylinder. The cylinder is then mounted on a carriage, which is moved along its axis by means of a screw, at the same time that the film cylinder is rotated. A small spot of light thrown upon the film is thus caused to traverse the entire film area in a long spiral. The light passing into the interior of the cylinder then varies in intensity with the transmission or tone value of the picture.

The task of transforming this light of varying intensity into a variable electric current is performed by means of an alkali metal photoelectric cell. This device, which is based on the fundamental discovery of the photoelectric effect by Hertz, consists of a vacuum tube in which the cathode is an

alkali metal, such as potassium. Under illumination, the alkali metal gives off electrons, so that when the two electrodes are connected through an external circuit, a current flows. This current is directly proportional to the intensity of the illumination, and the response to variations of illumination is practically instantaneous. This cell is placed inside the cylinder formed by the photographic transparency which is to be transmitted. As the film cylinder is rotated and advanced, the illumination of the cell and consequently the current from it registers in succession the brightness of each elementary area of the picture.

Assuming for the moment that the photoelectric current, which is a direct current of varying intensity, is of adequate strength for successful transmission, and that the transmission line is suitable for carrying direct current, we may imagine the current from the photoelectric cell to traverse a communication line to some distant point. At the distant point it is necessary to have the third element above mentioned, a device for retranslating the electric current into light and shade. This is accomplished by a device termed a "light valve." This consists essentially of a narrow ribbon-like conductor lying in a magnetic field in such a position as to entirely cover a small aperture. The incoming current passes through this ribbon, which is in consequence deflected to one side by the interaction of the current with the magnetic field, thus exposing the aperture beneath. Light passing through this aperture is thus varied in intensity. If it then falls upon a photographic sensitive film bent into cylindrical form, and rotating in exact synchronism with the film at the sending end, the film will be exposed by amounts varying in proportion to the lights and shades of the original picture.

The simple scheme of picture transmission just outlined must be modified in order to adapt it for use on commercial electrical communication systems. Of existing electrical means of communication, which include land wire systems (telegraph and telephone), submarine cable, and radio, the wire system, as

developed for the telephone, offers great advantage when all factors are considered, including constancy, freedom from interference and speed. The picture transmission system has accordingly been adapted to it.

In the simple scheme of picture transmission the photoelectric cell gives rise to a direct current of varying amplitude. The range of frequency components in this current runs from zero up to a few hundred cycles. Commercial long distance telephone circuits are not ordinarily arranged to transmit direct or very low frequency currents; so the photoelectric currents are not directly transmitted. Moreover, these currents are very weak in comparison with ordinary telephone currents. On account of these facts, the current from the photoelectric cell is first amplified by means of vacuum tube amplifiers and then is impressed upon a vacuum tube modulator jointly with a carrier current whose frequency is about 1,300 cycles per second. What is transmitted over the telephone line is, then, the carrier wave modulated by the photoelectric wave so that the currents, in frequency range and in amplitude, are similar to the currents corresponding to ordinary speech.

When the carrier current, modulated according to the lights and shades of the picture at the sending end, traverses the ribbon of the light valve at the receiving end, the aperture is opened and closed with each pulse of alternating current. The envelope of these pulses follows the light and shade of the picture, but the actual course of the illumination with time shows a fine structure, of the periodicity of the carrier.

In order that the light and shade traced out on the receiving cylinder shall produce an accurate copy of the original picture, it is necessary that the two cylinders rotate at the same uniform rate. This, in general, demands the use of accurate timing devices. The means employed consist of phonic wheels or impulse motors controlled by electrically operated tuning forks. Were it possible to have two forks at widely separated points running at exactly the same speed, the problem of synchronizing would be immediately solved. Actually this is

not practical, since variations of speed with temperature and other causes prevent the two forks from operating closely enough together for this purpose. If the two cylinders are operated on separate forks, even though each end of the apparatus runs at a uniform rate, the received picture will, in general, be skewed with respect to the original. Fundamentally the problem is solved by controlling the phonic wheel motors at each end by the same fork. For this purpose it has been found desirable to transmit to the receiving station impulses controlled by the fork at the sending end. The problem of transmitting both the fork impulses and the picture current simultaneously could be solved by the use of two separate circuits.

It would not, however, be economical to use two separate circuits for the picture and synchronizing channels; consequently the two currents are sent on the same circuit. In order to accomplish this, the picture is sent on the higher frequency carrier, approximately 1,300 cycles per second, and the synchronizing pulses are sent on the lower frequency carrier, approximately 400 cycles per second, both lying in the range of frequencies readily transmitted by any telephone circuit. These carrier frequencies are obtained from two vacuum tube oscillators. The two currents are kept separate from each other by a system of electrical filters at the sending and receiving ends, so that while the current on the line consists of a mixture of two modulated frequencies, the appropriate parts of the receiving apparatus receive only one carrier frequency each.[1]

It is pleasing to find on the reading table in the farmhouse as well as in the club, the modern product of the paper, the ink, and the processes to which reference has been made. Thanks to modern means of transportation, the postman brings regularly the letters, the papers with their news and market quotations, the magazines of travel and fiction, the photographs of foreign lands, the reproduction in color of the works of the great masters,

[1] "Transmission of Pictures over Telephone Lines," by Ives, Horton, Parker and Clark, Bell Telephone Laboratories, Inc., p. 2 *et seq.*

and all that innumerable list of factors in our modern civilization which make us thankful that chemistry could have contributed something toward their achievement.

Do you remember the days when even the city man had to go to "central" to answer a long distance call? Science had already done much in establishing communication, but had not yet undertaken to talk across the continent. Those who marveled at the possibility of telephoning from New York to San Francisco or from San Francisco to New York, if you happen to be a Californian, did not know that the development of such devices was one of those rare instances of an invention made to order. When plans were laid for the Pan-American Exposition in San Francisco, the officials of the American Telephone and Telegraph Company concluded that it would be a fine thing if they were able by the time the Exposition opened to offer a transcontinental service. Various lines of attack were undertaken. Some scientists believed that an extra powerful transmitter or receiver would be necessary; but this would have required every instrument to be used for long distance to be especially built for the purpose. A group of American physicists, chemists, and engineers decided that, if a way could be found to supplement the weak waves or vibrations set up by the human voice in speech through the transmitter and a method found for making up the losses on the lines without distorting the wave, a successful solution could be reached. Going back one hundred years to the fundamental work of Faraday and Oersted and adding to that the contributions of a large number of prominent scientists in the interim, we come to the vacuum tube, which acts as a valve and which makes possible bringing in on the wires large quantities of energy from storage batteries but keeping the sound waves the same in shape and character. This method of amplification, this balancing of the line, as it is called, makes long distance telephony its success of the present day and explains why communication with a distant city is often more satisfactory than intra-city conversations where the lines are not so carefully supervised.

A stone cast into still water gives rise to a series of ripples most pronounced near where the stone struck and fading away as the distance from this point increases. If stone after stone could be thrown in exactly the same spot, ripples of a given magnitude might be maintained and the finer ones might even reach an increased distance from the center. If there were some way of introducing more energy into the feeble waves distant from the center, these outermost waves might be increased in size to compare with those near the source of the impulse. Roughly speaking, what has been done in long distance telephony is to supply energy to these waves, that they may be kept at the strength of the initial impulse. This method of attacking the long distance problem made every instrument a long distance telephone, and even the rural telephone is found unsatisfactory only when all the other subscribers on the party line insist on taking down the receivers when they hear a call, that nothing in the way of news and gossip may escape them. This practice diverts so much energy that the original parties to the conversation have an insufficient supply left them.

Fifty years ago, there was just one telephone in the world; to-day in America alone there are more than sixteen million instruments. Less than fifty years ago, there were but two telephone employees, Alexander Graham Bell and his assistant; to-day there are more than 300,000. In America there are approximately twenty billion telephone communications a year. Suppose we tried to transmit these by messenger, instead of by telephone, giving each messenger nine working hours per day and making it possible for him to average ten miles per hour on his routes. It would take more than six million messengers to do the business now done by the telephone.

When there were but few telephones the problem of wiring was relatively unimportant and early photographs show an exchange in Boston covered with a forest of overhead wires. Overhead wires are particularly susceptible to blizzards and wind storms, one of which in the winter of 1881 threw 1200 circuits out of service at the Boston exchange. To-day that num-

ber of circuits is carried in a single cable less than three inches in diameter, and under the corner of Broadway and Franklin Streets, New York City, there are more than 35 cables, each containing on the average 700 telephone circuits, making a total of more than 47,000 wires under that single thoroughfare. The development of the modern cable has called for research in metallurgy and in paper making quite as much as in a study of electrical currents. Without increasing the size of the lead sheath carrying the cable a development of better types of insulation, beginning with rubber and proceeding to highly specialized thin paper, has meant that in place of fifty pairs of wires these cables may now carry fifteen hundred pairs without any detriment to the service these telephone circuits are capable of rendering.

On the metallurgical side, it is interesting to note that the first of the lead cable sheaths contained a 3% mixture of tin for the sake of mechanical properties. When the price of tin rose simultaneously with the increased demand for cables, a new formula was developed in which antimony was used with a resulting saving in ten years of six million dollars. Formerly the line wires of copper weighed 870 pounds per mile; to-day the line wires weigh 82 pounds per mile. For the submarine cable a new type of alloy has been developed in the research laboratory. It has remarkable properties, having a message-carrying capacity four times as great as cables now in use.

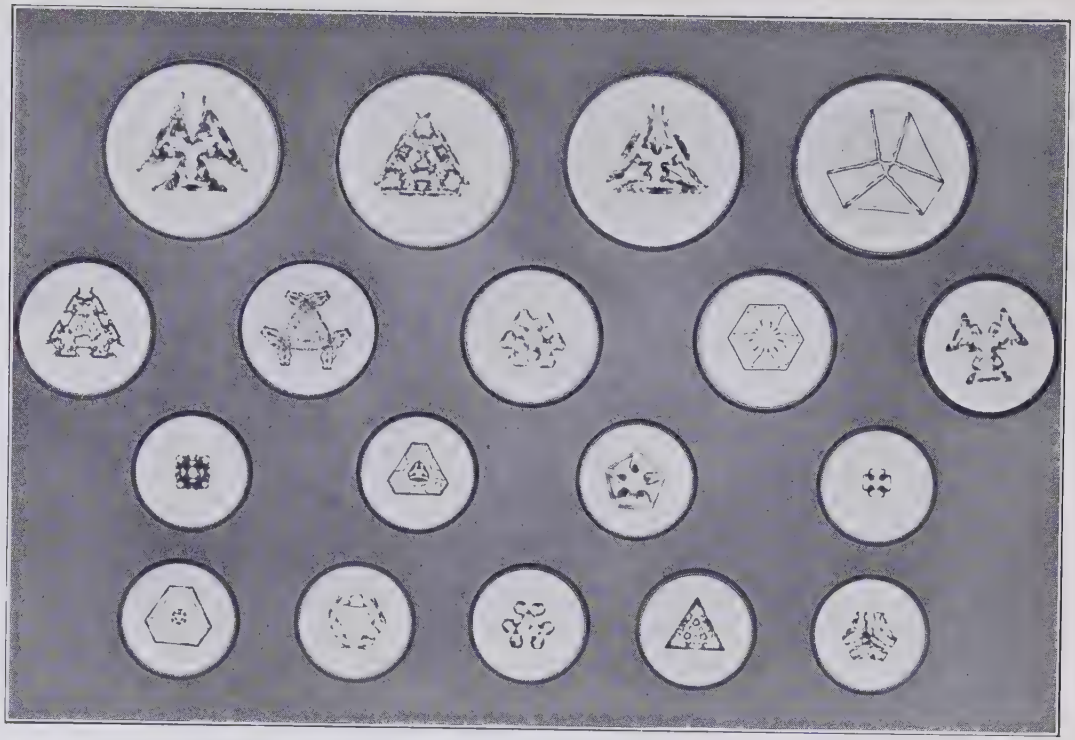
Wireless telephony, popularly known as the radio, though still in its infancy, laughs at time and distance. Some wag has said that a message can travel around the earth with the speed of light — 186,000 miles per second — but this bears no relation to the length of time it may take that message to penetrate from the receiver's ear to his brain. If the farmer desires to hear an address by the President of the United States, his radio permits him to hear the words a fraction of a second before those who are face to face with the speaker. His market reports, his weather reports, and his baseball scores go to him

BARS OF PURE SILVER.

The photographic industry is second only to the United States Government in the quantity of pure silver used. This safe contains a tidy fortune in pure silver bars. (Courtesy, Eastman Kodak Co.)

THE MANUFACTURE OF PURE SILVER NITRATE.

The work is done in great porcelain dishes under carefully specified conditions which guarantee the purity of the product. (Courtesy, Eastman Kodak Co.)



SILVER BROMIDE CRYSTALS.

The crystals of silver bromide photographed through a microscope, the magnification being 3,000 diameters. The photographic industry is founded on chemical facts, the most important being that certain salts of silver turn black when exposed to light. Silver bromide is one of the important salts of silver in photography. (Courtesy, Eastman Kodak Co.)

through the air. If he likes grand opera, it is available in season, or he may listen to the Army Band in Washington. Mrs. Farmer can enjoy discussions on all topics from styles to cooking and the radio seems to have broken down the last barrier in isolation. MacMillan, in the frozen north, was able to keep in touch with the world, and in a radio talk compared the difference in the experience of his party with the ill-fated Greeley expedition, which suffered extremely and lost men because there was no way of establishing communication.

The vacuum tube is the corner stone in our radio structure. Electrons which are beyond the vision, even when aided with the most powerful microscopes, do the work, and the few electrons on the heated grid can be so controlled as to make useful the stored energy of the battery with the feeble impulse received on the antennae through the air. Doctor W. R. Whitney has stated that the amount of energy received through the air and required to operate the receiving vacuum tube is so small that we have no accepted units with which to measure it. A broadcasting station located in Los Angeles and employing one-half horsepower of energy could be heard in Schenectady some twenty-five hundred miles away. Assuming that the energy from such a sending station travels in all directions as if it were the center of a sphere, the surface of the sphere having a radius equal to the distance between Los Angeles and Schenectady can be calculated. Then if we know the area of the antennae used, we can estimate how much energy of the one-half horsepower sending station is received. After making the calculation, Doctor Whitney discovered that the amount of energy used by a fly in crawling one inch on a vertical wall would be sufficient to operate that grid day and night for thirty-five years. He now refers to it as the "fly inch." If you are mathematically inclined, you can make the estimation yourself.

It is obvious without tedious recital that the metals, the glass, the moulded panel, the storage batteries, the charging devices are all the products of scientific research in which chemistry can claim a large share. The synthetic resins have proven

their utility in the radio field. These resins are condensation products of carbolic acid, which the chemist calls phenol, and formaldehyde, a material made from methanol (wood alcohol). These resins themselves, or with suitable fillers, can be made into moulding compounds, permitting metal parts to be moulded in place. They come from the smooth mould ready for use without further finishing, after having been subjected to suitable heat and pressure. The development of synthetic resins and their application to industry is one of the modern romances of chemistry and a contributing factor to the low cost of many electrical devices.

The fact that certain compounds of the metal silver turn dark when exposed to light is the chemical foundation upon which the photographic industry rests. Chemistry is also in evidence in the film whether it be a form of celluloid or some non-inflammable cellulose compound, in the sensitized paper, in the developing and fixing baths, and indeed pretty much throughout the art. But the really fundamental fact is the simple one above stated. Photography makes possible our illustrations and it has come to be recognized that visual instruction ranks very high among the methods of teaching. The motion picture instructs or amuses and may bring to the smallest nickelodeon a fairly intimate knowledge of foreign regions, an insight into current events, and a friendly appreciation of lands and of places with which we were formerly unfamiliar. Like many other useful instrumentalities, we occasionally find the motion picture misused; but, when at its best, it has few rivals in banishing solitude.

Now and again we seem on the verge of having speaking motion pictures and may look forward to their success in the not too distant future. The greatest difficulty appears to be that of synchronism, that is, having the sound reproducing mechanism produce the voice at the exact instant the motion picture image appears to speak. With the increase in the number of those who are lip readers, even small differences in time are fatal to the success of such devices. Just as still pictures have been

transmitted by wire and by wireless, so also have motion pictures been transmitted but as yet in a limited way over short distances. It is freely predicted that ere long those of us who are physically isolated may have for our enjoyment not only the music of the play over our radio, but the play itself.

Photography also makes possible the complete record. It can probably be shown that the race really made small progress until some method had been devised for passing from generation to generation a record more accurate than word of mouth. With photography in its various phases and the sound reproducing mechanisms of to-day, it ought to be possible to leave to posterity a real record of our age. We only hope that when some archaeologist discovers the records of our civilization, there may be preserved with our reels of non-inflammable film and our rugged phonograph discs of synthetic resin, the devices with which they may all be used and explicit directions for their use; otherwise, conclusions comparing well with some of those doubtless announced by our own archaeologists concerning past peoples may be reached.

A variety of chemical compounds have been used in sound reproducing devices; but the most rugged, permanent, and withal satisfactory record has been of the synthetic resin type. It has been the chemist's major contribution to this art.

This discussion would not be complete without reference to the service which chemistry has assisted in rendering to those handicapped by defective vision and impaired hearing. Perhaps you could not read these lines but for your glasses, always at hand. Eye glasses and especially the more refined optical instruments such as the microscope, the telescope, and the spectroscope are not made from ordinary glass. Indeed the manufacture of optical glass was considered so difficult and unpromising commercially that until the war compelled us to do so this glass was not made in America. Scientific work was in a state of arrested development prior to the plea made by the great German optician, Abbe, in the early 80's. He dreamed of photographic lenses, lenses for the microscope, the telescope, etc.,

impossible with the limited variety of glass then at hand. He pointed out the danger which existed because optical glass making was in the hands of a few and the supply of glass might be seriously interrupted by a single factory accident. His plea attracted Otto Schott, who later became the head of Schott and Genossen, the manufacturers of world famous Jena optical glass. A long series of experiments resulted in a few new glasses introduced in the early 90's, and soon there was established the relation between chemical composition and physical characteristics which marked the beginning of the development of new types of glass largely responsible, as parts of new scientific instruments, for many of the advances made in biology, in medicine, in metallurgy, and in a long list of the natural sciences.

The manufacture of optical glass involves, to begin with, the strict chemical control of all the materials entering into it. Mere traces of iron render the sand useless for the purpose, and similar requirements hold the characteristics of other raw materials within narrow limits. The factors of time and temperature are important, and the construction of special clay pots is an art and science in itself. These pots must be capable of withstanding the temperatures and the mechanical stresses involved, at the same time being as nearly insoluble as possible in the molten glass. The annealing process is one of great refinement, for internal stresses due to sudden cooling cannot be tolerated in glass for specialized purposes.

It was during the World War that American scientists were called upon to produce optical glass, and it is greatly to their credit that within a few months they acquired such knowledge of fundamental principles as to enable the needs to be met. Fortunately there was in America a group of chemists who had devoted their careers to studying the silicates, and their knowledge together with published data on the composition of certain glasses made it possible to draw a diagram, such that, knowing the composition of a glass, its physical properties could be predicted with a remarkable degree of accuracy. With such information in hand, the exacting requirements of the mathematical

optician could be satisfactorily met. A compound lens, consisting of two or more elements, may have each of these elements fashioned from a different kind of glass, and there are those who feel that once again progress will be delayed until further triumphs are recorded in this difficult field of applied chemistry and physics.

Eye glasses are made of a glass less difficult to prepare than optical glass, the limitations being less strict. The refractive index, the freedom from color, and such imperfections as striae and bubbles are important. To-day eye glass lenses are made in a variety of colors, shapes, and sizes never before attempted. Sir William Crookes, intent upon devising a glass that would protect the eyes from the heat rays, that is, the infra-red, and the ultra-violet rays, was unsuccessful in finding a glass that would do both, but did devise two glasses. It is claimed that one of these is capable of protecting against infra-red and the other of guarding the eyes against ultra-violet. While originally designed for industrial workers, lenses of such a glass have found much wider application.

The time has also passed when a man needs a card index for his spectacles. Those requiring different glasses for near and far vision are now supplied with a combined lens where two kinds of glass separately ground and polished are fused in an electric furnace, and after grinding and polishing, the line of demarcation between the parts is scarcely visible. More than that, for special cases where color fringes appear at the point where these glasses of different index come together, the individual may be provided with a single lens so ground and polished as to meet his prescription for near and far vision.

Not only is optical glass made under chemical control, but the various stages in the preparation of the finished lens call for the chemist's aid. There are abrasives, some of which are produced in the furnace of the electrochemist. There are polishing materials prepared from chemical compounds. There are cements, cleaning compounds, etching materials, lubricants used when drilling small holes in the glass, and the service of the

chemist and metallurgist in providing the frames, whether these be of imitation tortoise or of solid gold.

The photoelectric cell, to which reference has been made earlier in this chapter, has gone into the service of the blind. Selenium, a little known element and a by-product in the refining of copper, is also extremely sensitive to the smallest changes in light intensity and is used in another type of photoelectric cell. The slight differences in the light reflected from various parts of the printed page causes a difference in the electric impulses set up when these electric waves are converted into sound waves with the aid of a mechanism similar to that employed in sound reproducing machines. Sounds are produced which can be coded and understood by those who cannot read; in other words, the machine reads aloud the printed page. The device is called the Optophone and when it is fully developed should serve to relieve many a lonely soul of the feeling of isolation which blindness must bring.

As we learn more of the radio vacuum tube, progress is made in assisting the deaf to hear. The possibility of increasing or decreasing the volume of sound and of changing the pitch by the use of vacuum tubes actuated by small dry batteries enables such adjustments to be made that many interfering extraneous sounds may be tuned out. Already these principles have been employed in commercial devices of some popularity

It is difficult for us to conceive of the time when the only means of communication were the marathon runner, the signal fire, and the delivery by hand of certain emblems and tokens. The Battle of New Orleans in the War of 1812 would not have been fought had there been some way of advising the generals that peace had already been declared. History is dotted with instances where communication as perfect as that enjoyed today would have altered events and changed the direction of world affairs. Perhaps we are just on the edge of still newer developments which will render our present methods of communication as obsolete as the pony express and the stage coach.

Solitude? How can there be real solitude when a man can

equip his automobile with wireless, have his mail forwarded, pick up his favorite home paper in most of the cities, and if he wills, have the products of the world available to him wherever he goes? It only remains for a man to be friendly, if he would have friends.

Chapter III

ALLIES OF THE SUN

The rest and quiet of the evening and the peace of twilight would lose much of their charm for most of us, whether we dwell in country or city, if we knew that the night to follow would be one of unbroken darkness. Man has an instinctive dread, not to say fear, of night unilluminated. Witness, for example, the groundless fear of many a child in the dark, due no doubt to the experience of generations of primitive ancestors. In our day, when light is used so lavishly, it is difficult to imagine the conditions before man discovered how to make or transport fire. From the time lightning taught some observing creature that some things could be made to burn, until chance caused some bit of fat to fall in the fire, thus demonstrating the superior light-giving qualities of some substances, very little progress could have been made in the art of illumination. When night settled down, its dangers outside the narrow circle of the primitive fire must have seemed to be intensified.

Artificial light very generally depends upon burning or combustion. All around us are examples of burning at different rates under varying conditions. The material being burned is combining with the oxygen of the air. If it goes on with extreme slowness, as in the burning of iron, we call it rusting or corroding. It goes on more rapidly in a smoldering fire. But when the temperature is elevated or an increased supply of air provided, combustion may proceed rapidly enough to cause a light-giving flame to burst forth. As the temperature rises, the flame becomes brighter and then changes color, so that the experienced metal worker learns to judge within a few degrees the temperature of his metal by its color. Cherry red heat, yellow heat, and white heat, for example, are common phrases.

We raise the temperature still higher or supply pure oxygen and iron may be burned with a flame. But even this is not the limit, for under conditions which exist in the electric lamp bulb, a temperature is reached which causes even tungsten, the most difficult of all metals to melt, to glow with incandescence so bright that we endanger our sight if we watch the wire for too great a time. Just as differences in temperature produce different rates of burning, so also do differences in size. A homely example may be taken from our customary practice. We first ignite the match head by the heat generated from friction, then the match wood, the paper or shavings, the kindling, and progressively larger pieces of wood, until whole logs may be cast upon the fire.

Crude lamps fashioned from clay and sun-dried or burned, found in the depths of caves upon the walls of which appear primitive drawings, are the earliest indications that the race had found how to utilize light from vegetable and animal fats, waxes, and oils. Some one discovered that oils and fats in mass did not burn to advantage, but that small quantities could be vaporized by the wick, the heat of which promoted the vaporization of more oil, so that a flame could be maintained without the wick itself being consumed with great rapidity.

When the wick was invented, real progress was made, but genius seems to have divided its efforts between seeking new oils, fats, and waxes, and inventing endless varieties of lamps, candle holders, and the like. It seems obvious that the invention of the candle was the first step toward safety in illumination, for it permitted light to be transported with greater safety than where the oil lamp without protecting chimney or other safety devices was used. With the wick, which brings but small quantities of oil to the flame, protected with the chimney, we have a device so nearly perfect for the burning of oils that it has persisted to the present time. Mechanical devices for controlling the wick and the globe, the swinging lamp, the lantern, and all such devices, are so nearly modern

as to need no special comment. In such a combination, however, are to be found many examples of chemistry in your service.

The development of the present day match offers an illustration of the application of chemical knowledge to meet men's needs. Early in history the difficulties involved in procuring a fire or light were so great that, to save trouble and labor, the race early conceived the idea of a fire which would burn continuously. Fires were kept constantly burning in the temples and other public places. The earlier and common methods were those now taught by scouts in woods-lore — the rubbing together of two pieces of wood by any one of several modifications of the principal idea. This was later followed by the use of steel and flint and the tinder box. Next came the use of bits of wood dipped in sulfur which were ignited by sparks from glowing rags. These ancestors of the modern match had to be ignited from an outside source, and it was not until the beginning of the nineteenth century that chemical reactions were brought into play so that a splint of wood might be ignited directly. Berthelot discovered that chlorates in the presence of strong acids would cause the oxidation of combustible bodies and devised an instantaneous form of light consisting of a bottle of sulfuric acid, in which was enough asbestos fiber to absorb it, and matches made of splints of wood dipped first into sulfur and then coated with a paste consisting of the chlorate of potash, powdered sugar, and powdered gum arabic. When these heads were dipped into the sulfuric acid bottle, ignition took place. There were many disadvantages to this form of match, and, therefore, they did not entirely displace the tinder box method of producing fire. We are indebted to John Walker, an English chemist, who, about 1826, invented friction matches. It is supposed that these were composed of chlorate of potash, antimony sulfide, and starch used as a binder. These matches ignited upon being drawn over a rough surface like sandpaper; but much pressure was required to produce the necessary friction, which caused the

heads to be crushed or the ignition to take place violently. Since phosphorus is easy to ignite, efforts were made to introduce it into the match head composition. Finally, Charles Sauria succeeded in using white phosphorus in the early 1830's.

The first patent for friction matches in America was granted to Alonzo Phillips in 1836. Here again the match head was composed of a little chlorate of potash, much phosphorus, a binder, and coloring matter. This composition easily ignited the sulfur dipped splints, and the sulfur acted as a flame carrier from the heads to the wood. Soon sulfur was displaced by paraffin as a flame carrier, and this was a distinct chemical achievement, for paraffin is odorless and does not give rise to the objectionable oxides of sulfur which form when it is burned. These parlor matches have now been largely displaced by that type of match which may be struck anywhere and which was perfected about 1905. While white phosphorus was of great utility in producing fire and light at will, it gave rise to a terrible disease because of the poisonous nature of white phosphorus. "Phosy Jaw," as it was called, resulted from the attack of this disease upon jawbones. A great deal of research was conducted in many laboratories to find something to replace white phosphorus, and in 1898 it was discovered that the sesquisulfide of phosphorus was a satisfactory material to take the place of white phosphorus. Since 1913, no match of the strike-anywhere type has been made in the United States with white phosphorus, and a tax of such magnitude has been levied upon matches containing white phosphorus as practically to prohibit their manufacture in the United States.

We now have safety matches, which ignite only when brought in contact with compounds on the side of the box, this compound containing red phosphorus, while the heads of the matches are made of potassium chlorate with some slowly combustible material. The book or paper matches are also of this type. The efficiency and safety with which matches can be used as the first step in dispelling darkness is evidently due to applications of science and particularly of chemistry.

There are still those who can remember when kerosene was a dirty, dangerous substance which seemed to delight in smoking the lamp chimney no matter what adjustment of the wick was made; but that was before chemistry had begun to play its part in the refining of crude oils. It was also before the demand for certain fractions of crude oil called naphthol, petroleum ether, gasoline, etc., had arisen. In those days the refiner tried to work off as much gasoline as possible in his kerosene, for he had no market for the gasoline. To-day he cheerfully reverses the process and tries to sell as much kerosene as possible disguised as gasoline, for the demand has largely shifted from kerosene to gasoline. The lower boiling point of lighter fractions such as gasoline when present in a hydrocarbon oil used in lamps constitutes a dangerous element and gave rise to disastrous fires and explosions. The mixture became hot enough from the burning of the oil to ignite spontaneously, if the right proportion of air were present. After experimentation, chemists established temperature limits for the boiling point and also the temperature at which when a small flame was brought near, a flash would cross the surface of the test cup and go out. This is called the flash point and, with the boiling point, established constants enabling standards to be set such that kerosene became safe for household use.

An example of how rapidly applied science has changed the order of things in our generation may be taken from the recent experience of a University of Ohio professor. He was discussing kerosene before his class, many members of which came from rural communities, yet none of them had had personal contact with kerosene nor were they familiar with any homes still using kerosene lamps.

But there was another difficulty. Many crude oils, notably those of the early Ohio and Canadian fields, contained much sulfur, and if present in quantity in kerosene, hydrogen sulfide is produced when it is burned. This gas not only has the disagreeable odor of rotten eggs, but in large concentrations may be dangerous, as it is a poisonous substance. The removal

of the sulfur from the crude oil was a problem in chemistry. Herman Frasch, an American chemical engineer, discovered that the oxides of certain metals such as copper would remove the objectionable sulfur, forming the sulfide of the metal, and that this sulfide could be roasted, thereby driving off the sulfur and reforming the oxide for use again in the process. The application of this method not only enhanced the value of the crude oils in question, but removed both danger and inconvenience in the use of these kerosenes. As compared with the candle, the light efficiency of kerosene is nearly 50% greater.

But what of the lamp chimney? The earlier ones broke with great regularity, and before improvements in refining kerosene made it possible to maintain a luminous flame without an accompanying excess of soot, frequent washings meant frequent chimney breakage. There arose a demand for an improved type of glass for scientific apparatus; but, since the quantity used in scientific work is relatively small from a factory production standpoint, something that could be made on a production basis was sought for this type of glass. As a result, one glass plant, world famous for its optical and chemical glass, became a large producer of a type of lamp chimney which withstands sudden and extreme changes of temperature. This glass was a chemical product. At the time when the enclosed electric arc began to be used for street lighting, still another group of chemists undertook to make a chimney or glass vessel which would withstand the even greater changes of temperature found in such service. They found that a glass high in silica would withstand the sudden cold blasts of winter against the glass enclosed arc; but, by the time this chimney had been perfected, the enclosed arc was superseded and as a result there has been introduced into the kitchens of the country, glassware highly prized by the housewife as a cooking utensil.

When Murdock, an Englishman, conceived the idea of lighting the streets of London with gas made by the distillation or carbonization of coal, the city council at first refused to give him a franchise on the theory that his efforts would merely

result in the destruction of the city. By persevering, he was finally allowed to try the experiment and to-day even in the most modern cities we find a certain percentage of gas lighting. When the gas lighting industry was threatened with extinction with the introduction of the electric lamp, it was chemistry that came to its assistance by developing the famous Welsbach mantle. Welsbach discovered that if salts of comparatively rare elements found principally in monazite sand — cerium and thorium — were oxidized and heated to a high temperature they would glow, giving an intense light, the color of which was determined by the relative proportion of ceria and thoria. This was the beginning of the mantle industry, and the chemistry involved, first, in separating the elements from the monazite sand, in devising the best means of application, in determining the best fibers, and how they should be perfected for the mantle, forms the subject of a romantic story. Mantles are made of cotton, of ramie, of artificial silk, and other fibers, depending upon the service they are to render. These woven mantles are impregnated with certain salts of the elements described, in proportions to give light satisfactory in color, and the mantle is then treated so that it will withstand handling and transportation. When in place and burned off according to directions, there remains a network of the oxide or ash of cerium and thorium, which, with reasonable treatment, gives long service and high efficiency as a light source. With the Welsbach mantle we get four times the lighting efficiency of our old friend the kerosene lamp.

Different types of mantles have been perfected not only for street lighting lamps and lamps of other sorts, but for use with particular gases or vapors. Gasoline vapor, alcohol vapor, and the like are used in some places. In larger cities where gas plants are operated, gas is now made according to a heat standard, whereas before the introduction of the mantle, it conformed to a lighting standard. This called at times for the addition of hydrocarbons from oil, in order to make the candle power satisfactory. But since most of the gas is now

used for heating in light manufacturing and household pursuits and since the efficiency of the Welsbach mantle depends upon temperature, it is obvious how important has been the chemist's contribution to the perfection of the mantle at a time when most of the gas business depends upon heat units. In rural communities the Welsbach mantle finds application in the use of acetylene gas. The light produced is agreeable in color, satisfactory in intensity, and, where the conditions specified are observed, quite safe in use. Acetylene finds great favor in individual houses in many rural communities, although individual electric lighting systems are growing in favor. Acetylene made its commercial bow when a chemist, who was experimenting with various mixtures in an electric furnace, heated a mixture of coal and lime but failed to produce the expected product. Impatiently he threw it out of the open door, and it chanced to light in a pool of water left by a recent rain. He noticed gas bubbling to the surface, became interested, and found that he had produced calcium carbide, which, when wet, gives off acetylene. Calcium carbide is manufactured in an electric furnace from coal and limestone. It is generally known as the grayish substance used in the bicycle lamps in the days gone by, later in the acetylene lighting equipment of the early automobiles, and now principally as the source of acetylene furnished compressed in cylinders for metal cutting and numerous other uses. At one time there was danger accompanying the use of calcium carbide, for the devices then employed fed water to the carbide and, in case of leakage or faults in the control system, caused gas to accumulate to the danger point with accompanying explosions or fires. The carbide to water system, however, proved satisfactory, for the supply of carbide could be controlled, the carbide reacted completely with the excess water, and the pressure generated helped to ensure this control. However, to-day acetylene is so universally available in compressed form, another chemical achievement, that there seems no need for any difficulty in its production and use. Just as the mariner is often protected by the flashes of acetylene gas in

the gas buoy off shore, so also is the motorist warned on the country highway and in the cities of crossings or danger ahead. A gas accumulator, using acetylene, is the active principle of these highway lighthouses, which flash their warning at regular intervals.

The progress made in lighting efficiency and safety from the earliest times until the discovery of the electric lamp seems dwarfed into insignificance by the contributions of the electrical industry. Compared with the gas filled incandescent lamp of to-day, duplicates of the early incandescent lamps appear as toys, and yet the development has taken place within the lifetime of a single man. Chemistry has played a vital part in the production of the modern electric lamp, though the improved type of electric lighting has involved many sciences and the expenditure of vast sums of money on scientific research. Some of the problems involved are difficult to understand, more so to describe, but we may say that two important factors have been the filament, which is heated to incandescence, and the conditions under which this heating takes place in order that the filament may have a long life and high efficiency. By efficiency is meant the amount of light units that can be obtained for each unit of electrical energy which the lamp consumes. How seldom do we consider the tedious research of hundreds when we merely press the button or turn the switch to flood the room with light!

Edison, in America, and Swann, in England, produced the first practical incandescent lamps nearly simultaneously in 1879. Edison experimented with various types of filaments, but found carbon best. At first he used paper or cotton thread as the basis of this filament, but later employed bamboo fibers. By heating these to a high temperature in a furnace without air, they were charred to almost pure carbon threads. Later cotton was dissolved and the viscous fluid forced through capillaries into a hardening bath of alcohol. After drying, these threads gave smooth, even filaments, and a final improvement was made in carbon filaments when a dense deposit of

graphite was obtained on the surface from the decomposition of gasoline vapor.

But the scientist early recognized that metal offered great advantages as a substance for filaments. Tantalum was introduced in 1905 by Siemens, and while such filaments were not sufficiently rugged to be successful, they served to focus attention and research energy upon the perfection of metallic filaments. Obviously the metals which melt at the highest temperature were the ones to be used. Tantalum melts at 5250° F., tungsten at 5999° F. This very valuable characteristic adds to the difficulty of manufacture, however, for it is indeed difficult to work these metals. The low vapor pressure[1] of tungsten is also an advantage, and since the higher the temperature of the filament, the higher the fraction of energy converted into light, tungsten became the very center of research interest.

The early tungsten filaments consisted of granules of the metal held together with clay or other binder, and their life in service was short. A great many attempts had been made to produce ductile tungsten, and at one period in the development of the electric lamp a veritable race for the supremacy which ductile tungsten promised was staged between Europe and America. A combination of chemistry, physics, and engineering, backed by far-sighted capital, gave the prize to America. Tungsten cannot be worked as are other metals. The tungsten bearing ore is first purified and from it the oxide of the metal is prepared. Powdered tungsten is secured by roasting this oxide in a current of hydrogen. It is not possible to melt this tungsten powder except in the electric arc, which

[1] Vapor pressure may be defined as the pressure set up by the evaporation of a material into a closed space. Materials differ widely in this particular, the low boiling point liquids having in general the greatest tendency to evaporate and hence giving rise to the highest vapor pressures. When metals, even such as tungsten, are heated in a closed space, they, too, tend to evaporate and therefore develop vapor pressure. The ideal filament, among other characteristics, would have no vapor pressure; that is, would never evaporate from the wire to the bulb or other surroundings.

gives brittle, unworkable crystals. Therefore, this procedure is followed: The metallic powder is pressed into bars, which are then heated in hydrogen at a high temperature, during which time they partly sinter. A current of thousands of amperes is then passed through these bars, still in an atmosphere of hydrogen, and a temperature is reached almost great enough to melt the tungsten. The bar is now a homogeneous piece of metal, which is heated, swaged, reheated, and swaged again until a rod less than a millimeter in diameter has been produced. By repeatedly drawing this small rod through diamond dies, each of which is a trifle smaller than its predecessor, ductile tungsten wire is produced. Sometimes materials are added to the tungsten to impart desirable qualities, among them being thoria, the oxide of thorium, which helps to prevent large grains or crystals forming while the filament is in use. Tungsten filaments are operated at from 2100 to 2300° C., whereas carbon filaments do not reach more than 1700°. Because of the low vapor pressure of tungsten at these temperatures, lamps with tungsten filaments can operate a thousand hours or more before enough of the metal has been evaporated from the filament to the glass to discolor it sufficiently to cause it to be discarded. Because of the increased efficiency of the tungsten lamps, they are in universal use, the old carbon filaments finding employment only where the lamps are seldom used and a higher first cost not justified or where the more desirable tungsten lamps might tempt petty thieves.

Becoming interested in the properties of some inert gases and particularly their conductivity, Langmuir, a noted chemist, in the laboratory of one of our great electrical concerns, discovered that if the incandescent bulb is filled with a gas such as nitrogen or argon, both present in our atmosphere, much better results can be obtained than in a partial vacuum. With the object of preventing the rapid oxidation or burning of the heated filament, elaborate methods for drawing the air from the glass bulb and then sealing off the top had been devised for the manufacture of incandescent lamps. The better the vacuum

the better the results; but high vacua are difficult to obtain, especially where a large number of small units is involved as in lamp manufacture. Nitrogen and argon are inert or rather inactive gases; so there is no difficulty on this score. In manufacturing, the difficulties of displacing the air with such a gas are much less than those encountered in completely removing the air from the bulb, leaving the vacuum. Such a gas filled incandescent lamp with a tungsten filament is more than twice as efficient as the carbon filament incandescent lamp. More light may now be procured for a dollar than ever before in history, and the statement has been made that, had we used the same amount of light in 1892 with the best lamps then available, as was used in 1922, the people of the United States would have spent one and one-half billion dollars more for lighting than was spent in 1922, using our modern lamps. As it was, in 1922 it was estimated that one-half billion dollars was spent for lighting.

Other factors have contributed to the low expense of modern lighting. The chemist has been called upon to produce a glass having such physical and mechanical properties as to enable it to be blown by a machine, and most of our lamp bulbs are machine blown to-day. With the scarcity and high cost of skilled labor this has become an important item. Indeed, this glass has been made so rugged that it is no longer considered essential carefully to pack the blanks for transportation from factory to assembly. Mechanical devices have been developed for the assemblage of the many intricate small parts which make up the modern lamp.

Another factor has been the perfection of a combined wire which takes the place of platinum for the lead-in wires. In the days when an allowance was made for burned out lamps, it was on the basis of the value of the small amount of platinum used to conduct or "lead" the current to the filament. Platinum was used because it has practically the same coefficient of expansion as the glass with which it was used. That is, when heated or cooled they change size and shape at the same rate.

This meant no breakage or leakage from expansion or contraction. The new wire has a sheath with the desired coefficient of expansion and is used about another metal which is the core of a combined wire and carries the current. The two are drawn together and combine the desired qualities. It has been stated that the highest price ever paid for a patent without litigation was paid for the patent covering the production of this combination lead-in wire.

There are still many communities which have no access to electric distributing systems, and the achievements of science in dispelling darkness would mean little to them but for scientific achievements in other directions. Most electricity is generated by mechanical means. Steam, gasoline engines, and hydraulic power are used to drive generators, which transform mechanical power or energy into electrical energy; but electricity may be generated as the result of chemical reactions and may also be stored, thanks to the device called the storage battery. Gasoline motor and storage battery equipment are fundamental to most of the individual lighting equipments. In the storage batteries chemical reactions take place, lead sulfate being built up, broken down, and reformed, depending upon whether the generator is storing current in the batteries or the lighting system drawing the energy from these store houses. Improvements in storage batteries, a work calling for the close coöperation of the chemist, is believed by many to offer one of the best solutions for the problem of excess or off peak hydraulic power. By this is meant that part of the power continuously generated by the twenty-four hour flow of water for which there is no immediate need. Great storage batteries sufficiently cheap to justify their installation on a large scale would make it possible to store such energy against a later need.

The conversion of chemical energy into electrical energy is well illustrated by the omnipresent flashlight. Equipped with gas filled electric light bulbs and nickel-plated reflectors, thanks again to chemistry, this portable means of illumination supplied with powerful batteries gives great satisfaction. The electric

lantern should make it impossible for any cow to emulate her Chicago sister who is credited with having set fire to that city with a kick well placed on an unoffending lantern. The manganese dioxide, ammonium chloride, zinc, special insulating paper, the asphalt or pitch seal, the metallic terminals — in fact, all the elements which are assembled to make the familiar dry battery of the flashlight and radio — render an inestimable service, for they provide, among other things, an efficient lighting unit which may be transported anywhere with safety and which produces light at your bidding.

Reference has been made to the work of chemistry in the production of matches, which rank near the first in dispelling darkness. But improvements have been made upon matches. Some chemical substances such as that form of platinum known as platinum black have the facility of causing oxygen to combine so rapidly with them that they become red hot instantly. If this red hot wire or mass is brought into contact with the vapor of alcohol, for example, it is ignited. This is the scientific basis for one type of cigar lighter. The same principle makes possible the gas lighters, which cause the gas to ignite when the mass is held in the gas stream. Still another type is the pyrophoric alloy, a combination of iron and cerium, which, when struck with steel, produces a spark of great intensity. These friction cigar and gas lighters have been much in evidence and to the uninitiated are mysterious.

Scientists continue to seek cheaper and still better forms of illumination. Too great a proportion of the energy supplied to our lamps is wasted in heat. What is really wanted is cold light, in the production of which the firefly easily takes first place. Careful investigations have been made of the reaction accountable for the production of the firefly's flash, and it is believed to be a chemical reaction. There is no immediate prospect of cold light becoming available; but it seems fair to point out that the trend of scientific work has been steadily in the direction of greater light for a given quantity of energy. Ways have been found to imitate, if not duplicate, the efficiency of

nature in other directions, and it is not too much to expect that cold light will ultimately be achieved.

Meanwhile, there are undoubtedly many wives who still spend their leisure time in twisting tapers from old newspapers with which to light their kerosene lamps, that matches may be conserved. There are probably thousands who number among their daily tasks the polishing of lamp chimneys and the filling of lamps. Until chemistry and industry make it possible for all these homes to enjoy the safety, security, and comfort derived from modern methods of illumination, there will be much work to do. Meanwhile, there should be gratitude for what has been accomplished. Industrial efficiency and safety have been increased by proper lighting systems. Every day has been made a good day for manufacturing, so far as light is concerned, and in emergencies there is no difficulty in maintaining a twenty-four hour schedule. Darkness has been driven from our city streets, a factor in crime control, and vehicles have been so equipped as to make night driving safe. The humblest farm can replace the dangerous old fashioned lantern with a modern flashlight and everywhere devices are to be found with which darkness, in the past one of the limiting factors in the development of the race, can be banished.

Chapter IV

FOOD AND FAMINE

Famine conditions have constituted a menace to world progress since the very beginning, and time without number great sections of the earth have not only experienced great suffering and loss of life because of food shortage, but have as often been actually on the verge of starvation. The race early in its history sought types of food which would produce abundant harvests annually from seed and be capable of storage from one season of harvest to the next. Early civilizations learned empirically by experience many agricultural principles, the "why" of which science now endeavors to explain in the hope that a more complete knowledge of all the variables may effectively banish this threat of famine for all time. Thus, it is claimed that the famines of India are as often due to a shortage of money as to deficiency of rainfall, while at times the simple expedient of deeper plowing may enable the roots to penetrate to slightly lower water levels, thus insuring a satisfactory yield. We know that the annual overflow of the Nile was of the greatest agricultural importance, bringing a considerable deposit of rich loam, and that irrigation has been practiced for a long, long time. Natural manures have always played their part in maintaining soil fertility; but if we were confined to this material as a stimulant to our crops, we could not to-day maintain the world's granaries.

Chemistry recognized as such, began to perform its service to agriculture in the days of Sir Humphrey Davy, was emphasized by Liebig about 1840, and began in real earnest with the establishment of agricultural experiment stations, the works of the first of which was reared at Rothamsted in England. With the intensive application of the various sciences to agriculture the

uncertainties of that occupation began to be reduced in number. While obviously no scientist can control the most uncertain factors in food production, namely, rainfall and weather, yet it has been possible to point out ways in which many mistakes may be avoided. In practically all of this work chemistry is extensively involved, many of the problems lying clearly in its field and all the measures calling at least for accurate chemical analysis.

The physiological salt requirements of the plants is still far from being a settled question; but a few things seem to have been established. Most plants require potassium, nitrogen, and phosphoric acid. Traces of many elements are important. The length of day has more profound influence on growth and fruition than does temperature, and some gases, notably carbon dioxide, are important for purposes of growth. Scientific work in agriculture began with determining what it is the plant requires for optimum growth and the reproduction of its kind, gradually passed on to the stimulation of the soil by the use of fertilizers, and promises to culminate in an age of synthesis.

Phosphoric acid for fertilizer is usually prepared as the superphosphate or acid phosphate made by treating the phosphatic rock from the deposits of Florida, Tennessee, and the West with sulfuric acid. This makes a certain part of the combined phosphoric acid available for plant use and the remainder of the crushed rock plays its part as a fertilizer filler and to improve the physical condition of some soils. In passing, it may be said that the physical condition of the earth seems to be nearly as important as its chemical composition. Some successful work has been done in using quantities of sulfuric acid to produce phosphoric acid, which in turn is used in place of sulfuric acid on further quantities of rock. This yields a double superphosphate, having available two or three times the amount of phosphoric acid. Thus far such processes have only been attempted where sulfuric acid has been made as a by-product, as, for example, in the utilization of sulfur dioxide from copper smelters, and therefore is extremely cheap. The process finds further justification because the plants are located near rich deposits so

far removed from agricultural areas as to make it uneconomical to transport the ordinary forms or lower grades of superphosphate. America is fortunate in having great deposits of phosphate rock, and therefore the subject has not been so intriguing as potash and nitrates which have a real international significance.

There are other deposits of potash and there are certainly other sources for this precious material; but the wonderful deposits resulting from the evaporation of prehistoric seas in Germany and Alsace are by all odds the best known and the most important. In these mines one-half mile underground potash or potassium salt does not occur in the pure state, but in combination with other elements, forming a more or less complex mixture of salts. In an effort to reach underlying beds of common salt, sodium chloride, for commercial purposes, it is necessary to mine through a great overburden of these impure potassium salts, and it was the great Dutch chemist, van't Hoff, who showed the Germans how to apply physical chemistry to the mixture and prepare a potassium salt good enough for agricultural uses. From that day to this the potash situation of the world has been dictated by Germans, and while the Alsatian deposits are now under French administration a working agreement has been perfected between the two groups, leaving the world more or less at the mercy of the combination.

This monopoly would be quite complete, but for efforts made in the United States to apply chemistry to our own raw materials. Potash is found in many, many places, as, for example, the feldspars of New England and the South, the alunite of Colorado, and the "green sands" or glauconite of New Jersey; but in the case of most minerals it is held so firmly in combination that it cannot be separated at a cost to compete with potash from other sources. Even where the by-products have given promise of industrial application of great value, it has so far not been possible to work this type of potash resource, although some new work on "green sand" shows much promise.

The natural lakes of Nebraska contain some potash and were

worked during the war when the product was at a heavy premium. In those days of high prices, potash was also recovered from beet and cane molasses and from Pacific kelp, but the quantity was insignificant. Some prospecting has been done in Texas, and many believe deposits comparable with those on the European continent will be discovered. The only producing source of potash in America to-day is Searles Lake, California. Here is an ancient dried up lake in which is to be found a mixture of salts more complex and a great deal more difficult to separate than are those of the German mines. American physical chemists have gone far beyond the refined work of van't Hoff in devising ways to separate these compounds, and after first producing a potash containing small quantities of borax, have perfected their process until to-day an exceedingly pure quality of potash approved by the United States Department of Agriculture for fertilizer purposes is being produced at the rate of some 30,000 tons per year.

Both phosphorus and potassium have other commercial uses; but nitrogen surpasses them in demand and, since it is the basis of explosives, has been the center of intense interest and at times feverish research. Nitrogen began to be important with the invention of gunpowder, and the nitrates of that time were secured from natural deposits in India, where the presence of organic matter, nitrifying bacteria, and ideal weather conditions promoted the production of nitrates which crystallized on the surface of the earth. A few small wars and these deposits began to be inadequate, and we read of the perfectly terrible nitrate farms which were established in the hope of imitating nature and increasing the supply of fixed nitrogen. We speak of fixed nitrogen to distinguish it from the nitrogen of the air where it composes 80% of the mixture. We cannot use this nitrogen in industry, and even the plant seems unable to assimilate it unless it be present in some water soluble form such as the nitrates. In Sweden, in the days of her military power, taxes were sometimes levied in terms of nitrate, and it is recorded that even cemeteries were lixiviated, that the nitrogen

might be recovered from the soil in which bodies had been placed many years before. The great Chilean deposits were discovered in the middle of the nineteenth century and exportation begun in 1860.

More than fifty million tons have been exported to date and the extensive application of fixed nitrogen which this has made possible has made extensive agriculture intensive. Sir William Crookes, in 1898, called attention to the fact that, whereas the world's average yield of wheat per acre was then 12.7 bushels, the application of 150 pounds of nitrate per acre would increase this yield to 20 bushels, and then drew a gloomy picture of world starvation which would result from the exhaustion of the nitrate beds if any such extensive use were undertaken. Since wheat, for example, requires 47 pounds of nitrogen, 18 pounds of phosphorus, and 12 pounds of potash per ton, it will be seen there was a scientific basis for his prophecy. Since then, however, the Chilean deposits have been found of greater extent than was thought. New methods for extracting nitrate have been devised and, because of the military significance of fixed nitrogen, research has been carried to a point where the world bids fair to become independent in a measure, at least, of the natural nitrate deposits.

This work is an interesting example of how long a time may elapse between an original scientific observation and the industrial application of the facts established. Late in the eighteenth century, it had been noted that when an electric spark was passed through air in a test tube some of the nitrogen was oxidized or burned and that when these oxides were treated with water nitric acid would be formed. It was not until the beginning of the twentieth century, however, that Bradley and Lovejoy sought to commercialize this fact and to fix or burn or oxidize the nitrogen of the air by means of the electric arc. The air was caused to pass through gigantic arcs made fan or other shapes by electromagnets to increase the area of exposure. The process is full of difficult technicalities, for the reaction is reversible, that is, the oxides tend to break down to nitrogen and oxygen, and at best so low an efficiency is obtained that 68,000

kilowatt hours are required to fix a ton of nitrogen. This limited the plants to such countries as Norway, where electric energy is available in large blocks at attractive figures. Obviously this was not the final solution to the fixed nitrogen problem, for, from the point of view of some nations, while it was better to have two sources of nitrogen than but one away off in Chile it is still better to have a little fixed nitrogen plant in your home.

The next process to reach commercial perfection is known as the cyanamide, introduced in 1906, and depending upon the fact that when calcium carbide in pulverized and brought in contact with nitrogen such as may be distilled from liquid air a certain quantity of the nitrogen will be fixed. This process requires some 14,500 kilowatt hours per ton of nitrogen fixed, could be operated profitably in many places, and prior to 1912 was used more extensively than any other method for the fixation of nitrogen. But even this process required a great deal of power and power becomes expensive as our coal resources are used and new demands arise for it; so research continued in its effort to find a still more efficient method.

Ammonia contains one atom of nitrogen and three atoms of hydrogen in each molecule. Why not cause these gases to combine to produce ammonia, which can be oxidized to nitric acid and a whole list of things made from these two raw materials? Neither of these gases is inclined to be active. They prefer to lead individual lives, and so difficult was it believed to be to cause them to combine that at one time great chemists of the world regarded the synthesis of ammonia as impossible. However, that was before Haber, Le Rossignol and Bosch with their co-workers demonstrated that at certain high temperatures and pressures a catalyst would cause these gases to unite so readily as to be the basis of a successful commercial process. The nitrogen was obtained by burning the oxygen out of the air and purifying the residual gas. The hydrogen could be obtained by what is known as the water-gas reaction where water is passed through incandescent coke. The result is a mixture of hydrogen, carbon monoxide and dioxide. The carbon monoxide reacting fur-

ther with water forms carbon dioxide and hydrogen. However, the catalyst is sensitive to oxides of carbon and to water, and these must be removed. The carbon dioxide is removed by scrubbing at 50 atmospheres pressure with cold water, while one method of removing the carbon monoxide is to use an iron chromium catalyst and cause the carbon monoxide to form ammonium formate. This process for hydrogen, the first used, is so expensive to operate that 70% of the cost of the finished ammonia is represented by the operation; 20% in the making of the gases, and 50% in their purification.

Claude of France found that he could make hydrogen from coal gas by liquefying it, recovering the benzol and toluol which helped to pay for the operation, and finally separating the hydrogen from the carbon monoxide by a process of gas liquefaction. The carbon monoxide secured is burned or otherwise used.

Where the price of hydroelectric power is low enough, say, $10.00 per horsepower per year, current may be used to decompose water, giving an extremely pure gas; but this is not cheap and to date this process has been employed only where synthetic ammonia could be sold, as such, for refrigeration or other purposes at prices which returned a good profit on investment and operation.

The temperatures used in the synthesis of ammonia are on the order of 500 degrees C. and the pressures from 100 to 900 atmospheres, depending on the process. At the high pressures small reaction chambers can be used, good yields obtained, and the catalysts do not appear to be so readily poisoned by impurities in the gases. The synthetic ammonia process requires at present four thousand kilowatt hours per ton of nitrogen fixed, and with improvements in catalysts, by which is meant increased yield, resistance to poisoning, ruggedness, and long life, the tendency is constantly toward processes essentially chemical with lower power requirements. There is ample evidence that, whereas power was a deciding factor in the days of the arc process, hydrogen, cheap and pure, is the controlling factor to-day. The power used need not be electrical.

In the neighborhood of blast furnaces, from which great quantities of carbon dioxide are thrown into the air, experiments have been conducted with that gas which indicate that it does have a very decided influence upon plant growth. As yet, this has only been tried on small plots and there seems no immediate prospect of its commercial application; but we cannot tell when this established fact may come to be important economically. Methods are being sought for causing plants to store more calcium in a form which animals can assimilate. It seems to have been proven that sulfur is an important soil ingredient, that iron and manganese have their uses, so that agronomists of the future may need to be acquainted with the significance of a much wider range of elements than is represented by the old formula of three numerals which signifies the percentage available of nitrogen, phosphoric acid, and potash in a commercial fertilizer.

The chemist has helped the animal husbandman to establish important facts with relation to stock feeding. It has been shown that the calcium so important in our diet and largely derived from milk is taken from the skeleton of the cow; hence our interest in learning how to make available through the diet other calcium to keep the animal in healthy condition. The race horses of Kentucky are noted the world over and the blue grass of Kentucky contains a larger quantity of available calcium to strengthen the skeleton of the horse than is commonly found elsewhere. Chemistry has also helped to establish some important economic facts in animal feeding, for it has been shown that there comes a time when a steer literally eats his head off, for without change in feed he proceeds to replace with water a part of the fat previously accumulated at no little expense to its owner. Just as traces of elements are important in the soil, so also they are important in animal metabolism, though the full story is not yet known. The chemist has helped to make a promising start on the chemistry of the ductless glands, and the active principles of some of these have already been synthesized. Enthusiasts

predict that with a more complete knowledge of the chemistry of these glands will come the ability not only to control growth, but in the case of the human being to influence mental development as well and perhaps control sex. Indeed, if the prediction of these workers should come true, the power conferred through this work might be greater than the race could properly administer.

No discussion of food and famine could fail at least to mention the much advertised vitamin. While vitamins seem to have been isolated, we are not yet certain of their composition, and no doubt even yet some workers are undecided as to whether they are chemical compounds, enzymes, a form of energy or what not. Some even doubt their importance in nutrition which others ascribe to them; but feeding experiments, not only with animals but with large groups of children, would seem to confirm the view that the vitamins, of which we now list several, are an essential accessory to the diet. Children who often wondered wherein lay the benefits of cod liver oil can now be assured that it is the fat soluble vitamin A, while in many quarters the dairyman stands in awe of this same unidentified body contained in the cream, but not in the skimmed milk. It is an essential to body growth. Many a sailor has suffered from scurvy, not knowing that it was the scarcity of the anti-scorbutic vitamin that led to his undoing. Beginning with vitamin A, the list already extends to E, and we have been on speaking terms with vitamins only a short time. Recent work has shown that an oil, such as cottonseed, which has no vitamin A, can acquire the properties of a vitamin A bearing oil if exposed to ultra violet light. Rickets in infants is now cured by sunlight direct or through quartz windows or by vitamin A bearing foods.

The isolation and possible synthesis of fat soluble A is economically important, for we shall soon be confronted with new problems of milk supply involving shipping from distant sources for which even pasteurization and refrigeration may not be adequate safeguards. Already milk so dried as to leave its

physiological properties unimpaired finds its way to the market by the ton, and when it is learned how to add to skimmed milk, which contains vitamin B, the requisite amounts of vitamin A the problem will be simplified. Then, with the aid of a vegetable fat, milk can be made each day to order. Fats oxidize, causing rancidity, and while dried whole milk may be kept for months, dried skimmed milk may be kept indefinitely. There is, therefore, steady employment awaiting an inexpensive concentrate of the vitamin A or its synthetic duplicate.

The chemist is also helping in the matter of soil selection. Soil analysis, the physical condition of the soil and its acidity will be important factors when increase in population makes it necessary to allocate soils for particular crops. It has already been learned within what limits of acidity smooth scab-free potatoes may be raised. Organic indicators show by the color change how acid the soil is and this shows what quantity of lime to add to correct the acidity or its alkalinity and the sulfur that can be used to advantage to correct that condition, depending upon the needs of a special crop. Strange to say, so violent a reagent as sulfuric acid has been used experimentally on the alkali soils, where it not only corrected excess alkalinity, but happily produced an improved physical condition.

Just as three groups of chemical compounds have dominated the consideration of soil fertility, so also three groups have, until recently, held the center of the stage in human nutrition. Fat, protein, and carbohydrates have received most of the attention. Then came a discussion of calories, which still contend with vitamins for first place in the food discussions, having become so popular that some restaurants are accustomed to indicate on the bill of fare how many calories each item carries per single portion. Methods for adding weight and means for losing weight have all been based on calories; but now the physiological chemist wants to know not only fat, protein, carbohydrates, calories, and vitamins, but how the foods are split up by the digestive processes, what these products will be, the chemistry of their utilization by the body,

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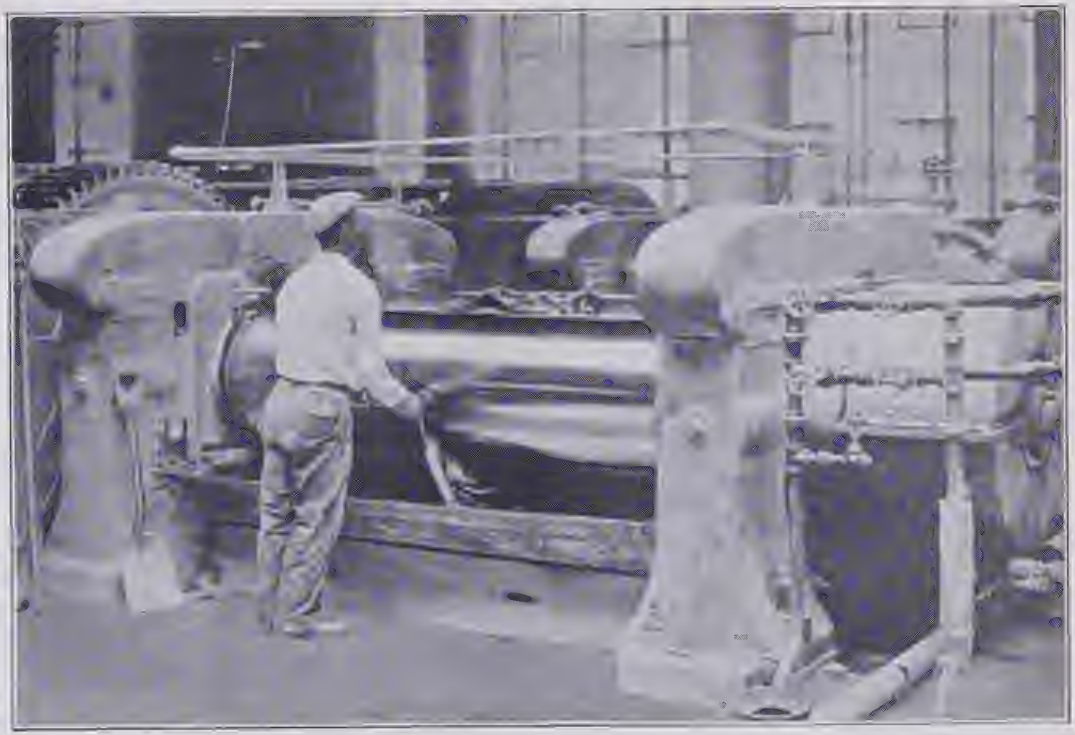
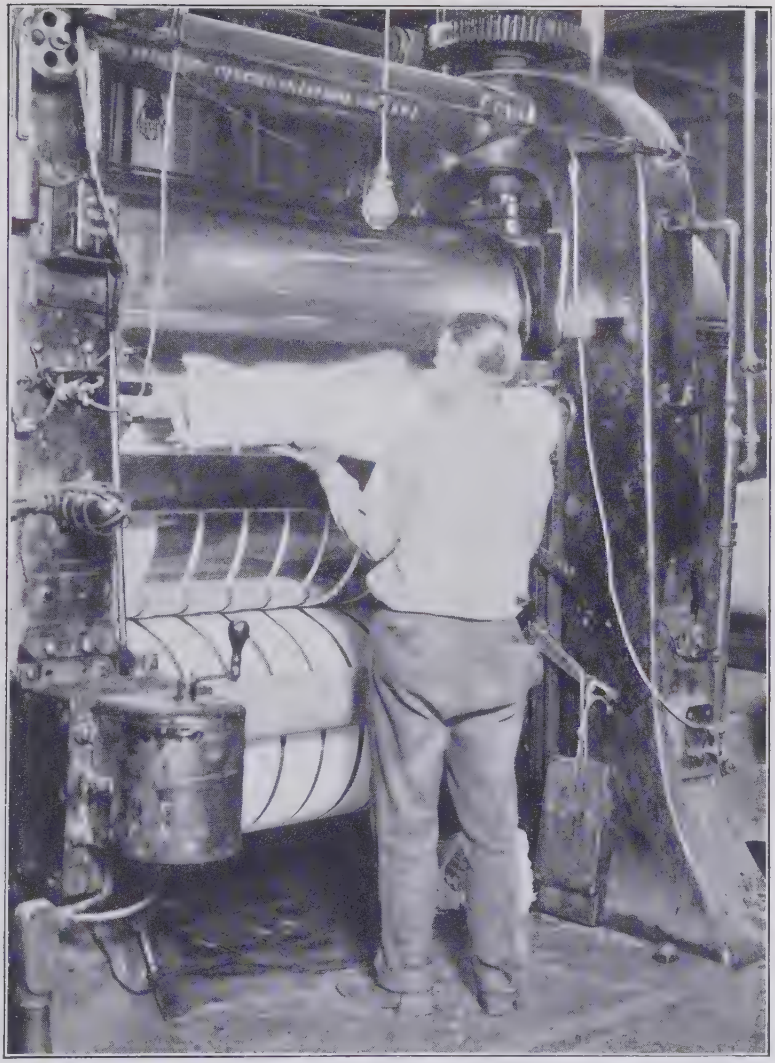


MIXING RUBBER ON A GREAT 84-INCH MILL.

Rubber is a highly complex chemical compound, and while mechanical devices have played a great part in making rubber products universally available, the improved quality of these products has depended upon chemistry. (Courtesy, Goodyear Tire and Rubber Co.)



Calendering and Cutting Rubber into Strips.

One of the important operations in preparing rubber compounds before vulcanization. (Courtesy, Goodyear Tire and Rubber Co.)

and their general influence on body growth and repair. For example, amino acids, of which cystine is one, are known to play a vital part in nutrition.

In the study of the influence of foods upon health, it was found that the carbohydrates — the sugars and starches — which have an even number of carbon atoms in their molecules are the ones which form acetone, leading to acidosis, fatal to the diabetic. Therefore, if a food having the calories to give strength to the patient could be devised with molecules with odd numbers of carbon atoms, this disastrous result might be avoided. Fortunately, this has been accomplished in the chemical laboratory and developed to commercial production. Of late, extensive studies have been initiated on the place of certain foods in the diet. Just what part does milk play in the diet of an adult, for example? What is the place of meat, of bread, and of other staples? The chemical difference between the type of milk which an infant can digest and that which causes distress has been determined. Every characteristic of human milk was established and upon these facts infant foods were built up from a mixture of fats and other ingredients selected on the basis of what the work on human milk had shown to be essential. The resulting food is correct in scientific principle and approved by the medical profession. It has been instrumental in seeing many an individual through the difficult days of babyhood.

Such studies as are in progress on milk, meat, and bread should be extended to other staples, especially those of comparatively high cost. Many consider sugar the most concentrated form of food and at the normal price the least expensive. A chemical study of the diet of various tribes and peoples serves to explain conditions otherwise mysterious, and if the prejudices and fastidiousness of some peoples can be overcome, this information should be helpful in planning a rational, economical diet. Many have pitied the oriental with his monotonous diet of fish, soya or mong beans, and rice; yet the laborer of the Orient performs a prodigious amount of

work on a diet which seems starvation rations to the occidental. One difference has been found to lie in the soya or mong bean as compared with the American Navy bean. The former in the digestive tract produces the types of amino acids of the greatest help to the body, while the Navy bean does not.

Problems of production, of balanced rations, of the most nutritious foods, and of diets chosen with relation to health, important as they are, do not touch upon another vital point. It has frequently been argued that the population of the world will be limited by the quantity of food that can be produced and this in turn will be determined by the amount of rainfall. We are therefore urged to preserve our forests, which are known to have a direct bearing upon rainfall. There is another fact, namely, whether man will be astute enough to win in his fight with insects and fungi for the possession of the fruits of his labor. Even before the seed is sown this conflict begins. By treating seed wheat with solutions of formalin or formaldehyde, for example, certain smuts can be overcome. Seed potatoes are also given the formalin bath and it is prescribed for other seeds as well. Similarly, copper compounds have been employed to destroy the spores of fungi or of bacteria or the eggs of insects to be found among the seed waiting to destroy the plant long before harvest time. Lurking in the soil may be the hibernating boll weevil, or some of his distant kin, ready to spring into activity with the coming of warm days and spring rains.

The more common insects like the potato beetle are known to all, and their ravages have been stopped by compounds of copper such as Paris green or of lead, like lead arsenate, by calcium arsenate, oil emulsions which cover the invader and prevent his breathing, and compounds designed to poison him when he eats or those which poison the dew and get him when he drinks. There are other insects more difficult, as yet, to defeat. The Mexican bean beetle is one which is very resistant, being helped by nature, which oddly enough causes far more females than males to hatch from a given lot of eggs and so

helps the tribe increase. Modern transportation, which has brought us so many blessings in other ways, has harmed us in the fight on insects. Insects brought from afar find in the absence of natural enemies an ideal home and frequently spread with great rapidity before a destructive parasite can be introduced against them or methods of spraying and dusting devised to halt them. The Japanese beetle is an example of this experience, and having gained a foothold in New Jersey, progresses on an average of six miles per year in an ever widening circle apparently oblivious of the millions of dollars that have been spent to seek its downfall. In Japan this beetle is not found in important numbers.

The spread of the corn borer has been facilitated by the automobile, and our almost losing battle against the brown tail and gypsy moths, the chestnut blight, and the white pine blister need not be emphasized here.

These questions are all serious from many points of view, and the chemist is coöperating with the entomologist and the botanist in an effort to devise effective methods of warfare. Researches are in progress on sulfur known to be efficient as an insecticide and fungicide; but just why it should be is not yet known. When this point has been made clear, perhaps our weapons may be made more effective against the tiny invader. Then there is the question of the adherence of these reagents upon the plants they are intended to protect. A limiting factor in dusting cotton against the boll weevil has been the expense due to the necessity of repeating the operations after a rainfall. If a method could be devised to have a sufficient quantity adhere to the plant, one or at the most two dustings might suffice for the season. At present dusting is at frequent intervals depending in a measure on the weather. Physical chemistry may play an important part here. The physical chemist would tell you that the green leaves of plants have a negative charge, and since like repels like in the electrical world, a dust or liquid to adhere ought to have the opposite charge. He experimented with lead arsenate and found that when made

with a positive charge the material adhered wonderfully well. It has been noted that dusts discharged under certain conditions from airplanes seem to acquire a certain tiny electrical force on their particles which has promoted adherence. If we could combine persistent adherence with dust delivered from airplanes over large areas, a great victory would be gained. Some years ago, a catalpa grove near Toledo was dusted from an airplane and this effectively disposed of the caterpillars. The airplane is on trial as a dusting machine for southern cotton fields and given an economical dust or spray may one day be used with great effect over great forest areas now threatened by certain enemies of our trees. It has already been approved for large area dusting.

Dips have also been devised by the chemist as an aid to overcome the cattle tick, the bane of stock raising in the South, and various insects which annoy and destroy animals in other quarters. Serums have been most effective against hog cholera, frequently saving great numbers of animals in a single season, and are comparable in value with the results from the use of insecticides and fungicides.

And when we have raised our crop and fattened our hogs, we have not finished. Some years 75% of the sweet potato crop is destroyed by little understood diseases before it reaches the table. Not only must such losses in storage be prevented; but we are in constant need of methods of preserving food and still leave it desirable for human food. The differences between bacteria and man are so slight that those things which are sure to kill the bacteria may be very harmful to those consuming the food. Formaldehyde is a perfect preservative for milk, but cannot be used on account of its poisonous character. The controversy over sodium benzoate is based on the same consideration. Refrigeration, universally employed in the preserving of food since it retards bacterial and mold growth, may be said to depend upon chemistry, since most of our ice is made artificially with brine cooled by the expansion of liquid ammonia, and we already use numbers of individual refrigerating systems installed

in household refrigerators and depending upon some such chemical compounds as ethyl chloride, carbon dioxide, ammonia, sulfur dioxide, and similar gases capable of easy liquefaction. Employing chemical principles a refrigerator has been devised in which ammonia is driven by heat from a solid absorbing medium, cools by expansion and is absorbed again. This is in reality a gas or electrically fired refrigerator!

Sterilization by heat, as in the process of canning food, and pasteurization at lower temperatures are at the basis of a great deal of our food preservation. Evaporation, as in sun drying of fruits or dehydration, which involves the removal of moisture by a method which leaves the cells of the fruit substantially unchanged, play their important parts. Dehydration seems to have a promising future. In many parts of the world we still insist on first quality only, leaving a great waste in the form of undersized, discolored, or misshapen fruit and vegetables which are unmarketable. We still think of dried fruits in terms of the old fashioned prune and the evaporated apple pie; but dehydrated materials are of another generation. In ordinary drying, the outer layer of the material readily gives up its moisture, thereby forming a sort of leathery covering through which the remaining moisture is extracted with such difficulty that the outer cells are destroyed in the drying process. When water is added, this material never assumes anything like its original form. Now dehydration may be done with air, the moisture of which is so regulated that it is nearly that of the material being dried, the difference being adjusted so that the moisture will be gradually drawn from a fruit or vegetable. This gives a product which, when water is added, very closely resembles the fresh material in size, color, and flavor.

The drying of milk, to which reference has been made, is another instance of the importance of removing water as one step in preservation which also has an economic bearing in the matter of storage and freight. Milk, for example, contains on the average $87\frac{1}{2}\%$ of water; some vegetables 95%.

In preservation, containers of glass and of tin have been de-

vised to meet most of the requirements. Extensive studies have been conducted on the relation of the coating of sheet tin on cans to the serviceability of the can, its pitting due to acids characteristic of fruits, and to discoloration which sometimes occurs, as, for example, with corn. The importance of vacuum has been studied, the heat penetration in such cans has been made the basis of research, while the chemical composition of the contents in its relation to the container is always under consideration. Waxed paper liners have been devised for some packages, such as those containing sea foods, and both varnishes and enamels have been devised for other types of cans. The relation of kinds of glass and the light rays permitted to reach food in glass containers is another research problem, as is the production of glass to withstand high temperature processing and mechanical handling.

Sugar, not ordinarily considered a chemical compound but nevertheless composed of carbon, hydrogen, and oxygen, is a well known preservative, as is also salt (sodium chloride) and vinegar, known chemically as acetic acid. Oil, whether olive or cottonseed, is extensively used; note sardines. Eggs also receive special consideration, for the nature of the shell makes it possible to utilize a chemical reaction for their preservation. If air is prevented from entering the egg, it may be kept suitable for use for a very much longer time than if air has ready access to the egg. The pores of the egg shell may be effectively coated with a silicate which seals, and this is the basis for the well known plan of "putting the eggs down" in sodium silicate or water glass as it is popularly known. Eggs have also been kept in oil, such as prime cottonseed, and before these methods were known and the reasons for them, it was customary to pack them in salt or sawdust. Great quantities of eggs are also dried, particularly duck eggs in China.

The chemist performs an important role as a guardian of public health through the inspection of foodstuffs and the drawing of regulations based on scientific work which govern methods and materials which can be used in preparing, preserving, or

otherwise treating food for human consumption. A great deal of research has been done on this subject, for exact methods must be worked out to enable the inspector, for example, to tell the difference between a really fresh egg and one which has been held in such good storage that it does not show the evidence of its advanced age in the way even a layman can detect. The effect of certain coloring matters on the health have been determined and the chemists have devised harmless food colors which have been approved, thereby enabling you to have a green cake on St. Patrick's day or a red, white, and blue one on February 22nd, if that is your pleasure. Where milk preservatives can be approved, limits have been set on the quantity permissible, and by a system of inspection, analysis, and research the food of the United States is protected to a greater extent than that of any other country.

Those responsible for this work frequently meet with amusing experience. A Chinese importer in Boston, for example, could not understand why the food inspectors would not permit a shipment of eggs from China to pass. These duck eggs preserved in a heavy coating of clay when opened disclosed black contents and showed a tendency to explode. This seemed evidence to the importer of prime condition, of a great delicacy; but he could not convince the chemist.

The question often arises to what extent will the chemist, who claims so large a share in the work of the world, be able to supplement our food resources when supplies become short. To this the chemist replies by pointing with pride to hydrogenation, a catalytic process which enables an atom or two of hydrogen to be added to the molecule of a liquid fat such as peanut or cottonseed oil to form a lard-like hard fat suitable for culinary purposes. He points to vanillin, the active principle of vanilla made from coal tar and the basis of most of the present day vanilla extract. So popular is this flavor that if the old source were to be relied upon, vanilla beans having come principally from Mexico, it would require the resources of fifty Mexicos to meet the present day demand. Special food such as the

odd carbon atom fat described above is of the same class, and while most chemists do not look forward to a time when the laboratory will replace the farm and garden, it is quite possible that in future the agriculturists will produce types of raw material like certain starches, sugars, and proteins, which, under chemical supervision, will be converted into concentrated types of inexpensive foods of which to-day we can no more than dream. Saccharin, the sweet coal tar product widely used as a sugar substitute or supplement, has no food value; but in future the laboratories may find a way to produce a substance of concentrated sweetness that shall have food value. But for a long time to come the principal contributions of the chemist to increasing food resources may be expected in better methods of soil fertilization, better understanding of plant needs, and improved processes for preservation and transportation.

There is always the possibility of developing new sources of food. One tribe or nation may include in its diet an item quite unknown to other peoples, and modern transportation is gradually introducing such new items into the diets of all people. Occasionally an entirely new source may be uncovered. An example is the recent work which seems to demonstrate the possibility of making levulose on a commercial scale from a descendant of the Jerusalem artichoke. Levulose is one of the numerous family of sugars, is sweeter than sucrose (cane sugar), and is so readily soluble that it may dissolve in moisture absorbed from the atmosphere. This introduces a problem in storage and handling levulose, but it is not an insuperable one. The Jerusalem artichoke is a well-known weed, but it is the ancestor of the mammoth white French Jerusalem artichoke already recognized as a valuable stock food and offering such advantages in cultivation, storage, and general utility as to indicate the easy possibility of persuading farmers to raise it as a food crop as well as for the raw material of levulose manufacture.

Another consideration is the part played in cost reduction. The value of stockyard by-products is a story giving basis for

the old saw that nothing was lost save the squeal, to which the paper man replied in speaking of his raw material, the tree, that nothing was wasted, not even the bark. In the citrus fruit industry, losses have been avoided by the application of chemistry to by-products including citric acid, lemon oil, and pectin made from culls and surplus fruit. In beet sugar, the pulp goes into stock food and the molasses may be a source of alcohol, cyanides and potash. The waste molasses of the cane industry constitute our greatest source of raw material for industrial alcohol. Potatoes are also used for the production of alcohol; but in this case a special variety containing too much starch to adapt it for human food has been evolved for the particular purpose.

Agriculture, being the oldest industry, has devised for itself so many laws and customs and has seemed to establish so many facts during its thousands of years of existence that it accepts the proffered aid of science with some hesitancy. We may be sure that whatever has been accomplished so far is but the beginning and in agricultural research there remain great opportunities for patient, persistent workers. These problems are in entomology, phytopathology, plant breeding, soil science, animal husbandry, — in all of which the chemist will find room for his work. The world is to be searched for special kinds of plants for peculiar locations where moisture conditions, soil conditions, times of frost and winds are major considerations. We can go back profitably and inquire whether the early breeding of certain wild strains of swine has given us the best that might be had by a careful selection of parents for a new race of hogs.

There are tremendous wastes in the agricultural industry which, if they are to be conserved, will have to find employment in industries essentially chemical. Already some success has met the efforts of those endeavoring to produce the artificial manure carrying all the bacteria which distinguish natural manure from chemical fertilizers for special uses. The protein content of wheat is not increased by present fertilizers and ways must be found for emphasizing the particular content of a plant

just as has been shown possible with corn where oil, starch, or protein can be varied with fertilization and methods of cultivation or as starch has been emphasized in a certain strain of German potatoes. Surely in agriculture, in the work to constantly render the world more immune to the attacks of famine, chemistry, having already demonstrated its potentialities in this service, is destined to find an unusual opportunity for the employment of its talents.

Chapter V

CONTRIBUTIONS OF CHEMISTRY TO CLOTH AND CLOTHING

It is only in rare instances that the products of nature are considered satisfactory for the needs of men. They must be changed in some particular to facilitate manufacture, or perhaps it is a question of refining or otherwise changing dimensions, color, and other characteristics. In no general field is this more true than in the production of textiles no matter what their application. Until recently the principal contributions of chemistry in this work have been with the preparation of natural fibers and supplying finishes for the completed cloth to give some particular feel or finish. During the last few years, the chemist has proceeded to produce the fiber itself in quantities so large that the market for certain natural fibers is being threatened.

Of course, chemistry, although unrecognized as such, has always played a part in the manufacture of textiles, just as other industries from time immemorial have been founded on chemical processes, though not so called. Primitive soaps, for example, were made with lye leached from hardwood ashes and animal fat. The modern method of producing soaps used in the manufacture and later in the cleansing of textiles is based upon the same chemical principles; but the work now proceeds under definite chemical control with more specialized objects in view, such as the provision of a soap with selected characteristics for special purposes. Primitive bleaching came down practically unchanged to within less than one hundred years of our day, and when the cloth to be bleached was spread upon the grass, bleaching occurred with the release of small quantities of hydrogen peroxide produced under the natural conditions of light and moisture. How impossible it would be to spread the miles of

cloth now made upon the grass to bleach, waiting patiently until nature could turn the trick and having at hand many people who could quickly roll up the cloth and put it under cover in case of stormy weather. There was little danger of overbleaching with its resultant tender fiber in the days when sunshine and dew did the work; but overbleaching only occurs where operatives have been careless or where the chemist's control is either absent or imperfect. To-day with ozone, hydrogen peroxide, or chlorine a satisfactory bleach may be secured without injury to the cloth in a very few minutes and production is not impeded. At one time, it was thought that even bleaching with chlorine required some forty-eight hours; then a chemist showed that a smaller number of minutes would suffice and that probably the reaction proper took place in a few seconds. The saving effected in equipment, the amount of goods in process, and similar factors contribute to lower prices of white goods.

The primitive dyes were vegetable, animal, and mineral substances. Logwood still furnishes a favorite dye for black silk. Indigo continues to be produced on the fields of India, and alizarine was for hundreds of years derived solely from the madder root. To-day we find these dyes made as chemical products, the result of chemical research, and they are the molecular equivalents of the natural product. Tyrian purple and cochineal are examples of pigments from animal sources. Tyrian purple was secured with the aid of a viscous fluid, a drop or two of which was obtained from the dorsal vein of a shell fish, Murex, found along the Mediterranean. The financial power of Tyre and Carthage depended to a large extent upon the monopoly in Tyrian purple, and near the sites of those ancient cities piles of Murex shells have been found by archaeologists. Those must have been the days when slaves were required to take great risks in bringing in huge quantities of the shell fish required by the demand. To-day we know this Tyrian purple to have been dibromindigo and dibromindigo of superior quality has been produced in American chemical factories. The resulting purple is more fast to light and washing, more homogeneous

in quality, and more pleasing in the range of its shades than anything which a Roman Emperor could command.

An obvious modern contribution of chemistry to textiles is the chemical rainbow. With an improvement in the quality of man-made dyes and the increase in the number of colors and shades, there has been a decided tendency toward employing color with a lavish hand. The manufacturers of the better textiles maintain their position by employing skilled designers, trained in the art schools at home and abroad, who constantly devise new patterns, new combinations of color, and unusual figures which become the mode of the moment. The enthusiasm of these designers is sometimes embarrassing to the chemist, for fashion may decree a certain shade on a given fabric without taking into consideration the commercial possibility of doing a satisfactory piece of dyeing. The dyer who must meet a specification or miss a season's business naturally uses whatever reagents may be at hand, sometimes with results which bring discredit to the manufacturer of dyes. However, he least of all deserves it. For example, a lady purchased a beautiful blouse, the material being a heavy silk attractive in an all over pattern both new and novel. The first time it was worn she found that even a handkerchief lightly brushed on the surface of the blouse came away colored pink. The goods had simply been padded, by which is meant lightly dyed on the surface probably with a top color which in combination with underlying shades helped to produce the unique effect. There had been no attempt to secure permanence.

The story of synthetic dyes has become known to nearly every one because the coal tar colors have sprung into international importance, and beginning with the time when the Central Powers endeavored to harass America by denying to her the colors needed, the technical and daily press have been filled with arguments on all phases of the dye question from their fastness to light and washing to the desirability of a tariff embargo. It will be sufficient, therefore, to say that the coal tar colors were discovered by Perkin, an Englishman, who,

while engaged upon an effort to synthesize quinine, found he could make mauve. Seizing upon the idea and bringing into their country some of those who had assisted in the work, the Germans began to specialize in coal tar colors, devoting to their development a colossal amount of high grade research consistently backed by liberal financing. One after another new colors were prepared, their method of application standardized, and research turned in other directions. Since perhaps 80% of the world's goods is dyed black or blue and as indigo, formerly obtained principally from India, is the largest single item, the synthesis of this material in the laboratory made a strong appeal to the German scientists. It has been said that over a period of five years research was concentrated upon this problem and 29,000,000 of gold marks expended before indigo had been produced. The contact process for the manufacture of sulfuric acid came about through this endeavor to make indigo, for large quantities of cheap acid are necessary. Failure threatened until a clumsy assistant left to watch one step in the experimental work broke a thermometer and it was found that the presence of mercury was required to obtain the end sought.

Coal tar colors have not only been developed to the point where more than a thousand and one are listed, but research continues for the simple reason that certain qualities not now possessed by some of the groups would be highly desirable. As knowledge is increased in new directions, whole families of new colors may be brought into existence. We already have nearly thirty classes of synthetic organic dyestuffs, some with names as long as a line on this page. One of the most important is a group of indanthrenes distinguished by their great permanence and fastness even to boiling in bleaching solutions. As new fibers have been provided, some have called for new classes of dyestuffs, and the combination of fibers used in textile novelties presents complex problems to the dyer. Sometimes a number of fibers are woven together, certain ones like natural silk being used for a particular pattern with the express purpose of dyeing the gray goods with colors so selective in their action that a large variety

of color combinations to meet the fancy of fashion may be made on short notice.

Of course, color may be applied to the fiber before it is spun into yarn. The yarn itself may be dyed or the piece of goods may be dyed after weaving, this method being known as piece dyeing. Frequently color is printed on cloth from engraved copper or other rolls, each of which applies a particular color as in any other printing operation. The dyes are made into inks with some readily soluble vehicle like glucose, without which sharp demarcations at the borderline of colors would be impossible. Sizes may also be used to prevent the spread of color through capillary absorption. Novel effects are also obtained by the use of chemical compounds, which discharge color from the spots where they are applied. A piece of goods may be dyed, therefore, and delicate patterns worked upon the background by the application of these discharge compounds. Sometimes a pile fabric like plush may be either topped with some color which just touches the tips of the pile fibers or, conversely, the color may be discharged from these tips, producing a pleasing effect. This method, for example, enables an elegant silk pile fabric to be dyed to closely imitate all the colors of natural sealskin, so that when the fibers are parted, they show the peculiar yellowish brown tint characteristic of dyed sealskins.

Starches and gums are important to the textile manufacturer, for they enable him to produce a wide variety of finishes without which it might be difficult to dispose of his wares, even though the pattern and the workmanship commend themselves. Textile finishing is an art in itself, highly developed, and the basis of prosperity of a number of large mills.

In the treatment of each fiber, we find several chemical processes. Wool is scoured and the animal fat removed by washing in hot soap water from which the grease is later recovered for sale. The refined grease is the lanolin of pharmacy. Another plan is to dissolve out or extract this oil or fat with some such volatile solvent as naphtha, which can later be boiled off under

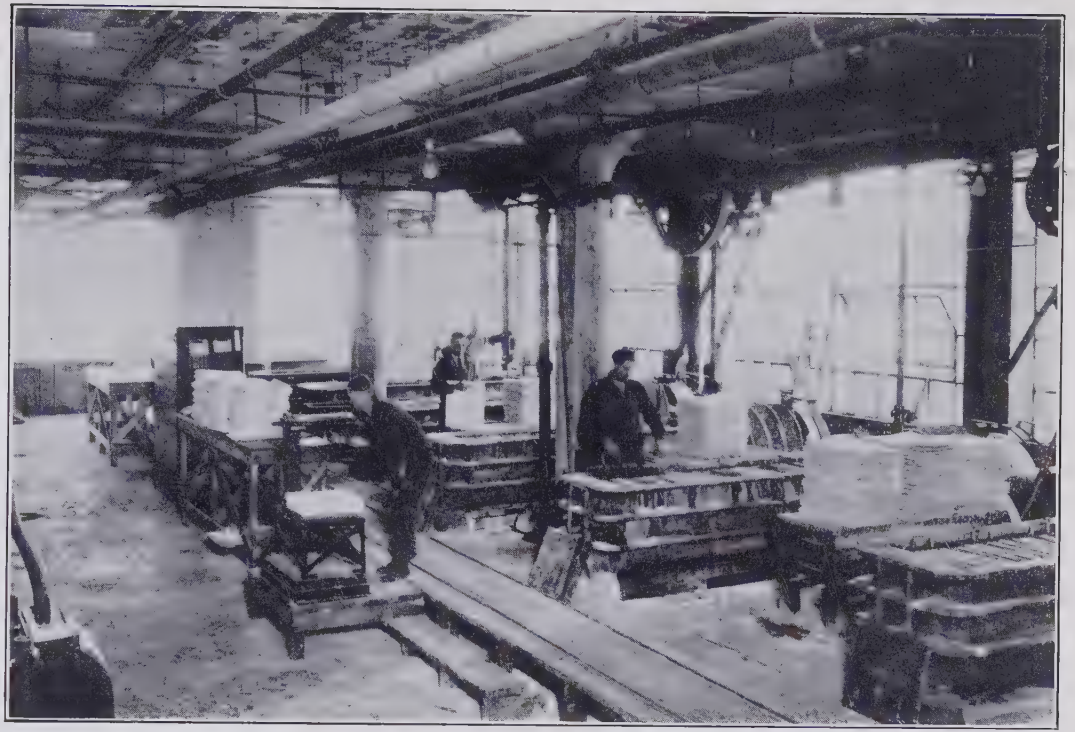
heat and pressure, leaving the fat behind. When natural silk comes to the mill, it contains about 25% by weight of the wax called sericin used by the silkworm to cement the fibers as they are spun from his spinneret. This sericin is "boiled off," using a soda soap solution. So far no satisfactory use has been found for this sericin.

Where wool contains foreign matter such as burrs, it may be treated with sulfuric acid which carbonizes the extraneous material, that is, cleanses the wool without material effect upon it.

During manufacture, chemical methods are employed sometimes to change the character of the fiber. A notable instance is the mercerization of cotton. John Mercer, an Englishman, found that, if cotton is treated with a 20% solution of sodium caustic and then held under tension to dry, it not only assumes a lustrous appearance, but may increase 20% in tensile strength. The latter is due to the fact that cotton fibers are much twisted and bent. All these various kinks are weak points, which become still weaker when the fiber is dry. If the fiber be straightened, therefore, the ease with which it may be broken is greatly lessened. The mercerization of cotton is an interesting illustration of how chemistry at work may change the class in which a material falls. Mercerized cotton helped to lift cotton out of the class of more common fabrics and make it prized for its new properties.

More recently it has been found that if the cotton fiber be treated with an acid such as nitric acid in place of an alkali such as sodium hydroxide quite a different effect is produced, the cotton becoming more like wool.

While cotton, flax, silk, and wool make up the great bulk of textile fibers, many others are employed on a varying scale. Ramie is a long silk-like fiber obtained from grasses in China. The fiber of seaweeds has been used. Jute and hemp sometimes find a place in textiles, and among less civilized peoples native grasses without much treatment of any kind may be employed. The cocoanut tree, famous because it provides man



PRESSES FOR THE MERCERIZATION OF CELLULOSE.

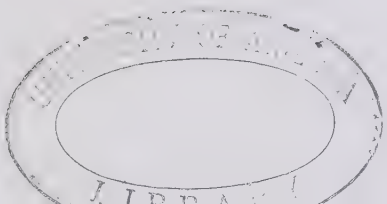
This is one of the first steps in rayon manufacture. The spruce pulp, cut in sheets, is soaked in an 18 per cent caustic soda solution, forming what is known as soda-cellulose. The excess caustic soda is removed in these hydraulic presses. (Courtesy, Industrial Fibre Co., Inc.)

AGING OF VISCOSE.

The orange-colored viscose liquid is kept at a low uniform temperature in these vessels and after the proper time is pumped under pressure to the spinning machines. (Courtesy, Industrial Fibre Co., Inc.)

Inspection of Rayon.

(Courtesy, Industrial Fibre Co., Inc.)



with food, drink, clothes, and shelter, contributes cocoanut fiber to local domestic textile industries.

But next to dyes, and some day we may have to say "and comparable with dyes in importance," is chemistry's contribution of man-made silk. For years this has been known as artificial silk; but now (1926) the world is in fairly unanimous agreement that hereafter this product shall have a name of its own, since it is a distinct product, and rayon is the term selected.

Artificial silk, as it was then called, was first displayed in 1889 by its inventor. Scientists had noted how the silkworm is really a converter of cellulose, in the form of mulberry leaves, into silk fiber and concluded that, using the cellulose of wood, they should be able to do in the laboratory what nature did through the medium of the silkworm. This suggestion had been made as early as 1742; but it remained for the French nobleman, Hilaire de Chardonnet, to conceive the idea of forcing a solution of cellulose through very fine openings into setting baths composed of solutions in which the cellulose would be insoluble. Little did he dream that within forty years fibers based upon his invention would revolutionize the textile industry. One of the difficulties to be overcome was the preparation of an orifice sufficiently fine to imitate the opening of the spinneret in the silkworm. Among the clever devices employed was to seal very fine wires into glass and then dissolve them out in acid, leaving the glass opening. To-day a platinum spinneret is universally employed. This spinneret has a large number of holes as fine as could be wanted, and when the spinneret becomes worn the platinum may, of course, be reworked.

To-day sulfite paper pulp is the most extensively used raw material for rayon. It is made from coniferous trees, principally spruce, by a chemical process, and comes to the rayon plant in great sheets of white pulp. Cotton linters, the short fiber carefully cut from the seed separated by the cotton gin, is also finding employment in this industry, particularly for one of the distinct kinds of rayon.

Chardonnet formed more than one company which failed before his last was signally successful. In 1891 rayon began to be made on a commercial scale in France; but it was thirty years before the new fiber was standardized both as to chemical process and mechanical handling, giving a thread sufficiently uniform and strong enough to compete with natural fibers. The greatest advances have been made since 1920 when the users began to be genuinely interested in this man-made silk.

There are four processes used in this industry. As has been said, the raw material is practically identical for all of them and they differ principally in the solvents employed. There is a natural cellulose process, which is the original Chardonnet silk. In it purified cotton is treated with sulfuric and nitric acids, forming nitrocellulose, which is then dissolved in alcohol and ether. The resulting solution is forced through spinnerets into fixing baths where the filaments are coagulated, the alcohol and ether are recovered, and the nitro groups removed, that there may be no danger in the use of the material. The thread is then bleached and is ready for sale. In another method an ammoniacal copper solution is used to dissolve the purified cotton or wood pulp. A spinning solution is made and the thread is coagulated by caustic soda or sulfuric acid. Bleaching prepares this thread for the market.

When the raw material is dissolved in acetic anhydride, treated with acetic acid and sulfuric acid, and the resulting material dissolved in acetone, the spun thread is a cellulose acetate. This type of rayon is unique since it is slow burning, if not inflammable, and requires a special class of dye for its successful coloring. Further, it is stronger when wet than other types of rayon. It is not only sought for special uses, but is frequently spun or woven with other fibers. In the piece it may be left undyed, giving on account of its high luster a brilliant fancy thread throughout the pattern, its color determined by treatment of the yarn before weaving.

By far the greatest quantity of rayon is made by the viscose process. It accounts for fully 80% of the total present world

production. Bleached spruce pulp, cotton linters, or a mixture of the two, is the raw material. Pulp generally is used. It is treated with caustic soda solution, forming a compound called soda cellulose. The excess caustic soda is removed under pressure. The soda cellulose is shredded, then permitted to age, after which it is converted into cellulose xanthate by treatment in suitable equipment with carbon bisulfide. This solution is called viscose and, after a ripening process, is pumped through mechanical regulators to the spinning machine where the platinum spinnerets or nozzles cause the thread to form. Sulfuric acid is one of the components of the setting bath which coagulates the material, producing regenerated cellulose. After purification and bleaching, the skeins of silk are washed. They are wrung in a centrifuge and dried and then graded for quality and are ready for the weaver. A ton of purified sulfite pulp makes about forty-five million yards of standard size yarn. The price of the raw material wood pulp is about five cents a pound, while rayon sells for two dollars a pound or upward. This added value by a manufacturing process must be credited to chemistry.

Rayon is soft and pliable. The size of the threads is determined by the opening of the spinneret and the pressure under which the viscose is forced through it. The production has grown phenomenally, doubling in some years and passing the 100,000,000 pound mark in 1924. $100,000,000 are invested in the industry in America alone where 40% of the world's output is produced. In 1913, 1,500,000 pounds of rayon were made in America; in 1925, about 55,000,000 pounds. According to some authorities, the production and consumption of rayon to-day is in excess of that of natural silk.

Chemistry may serve the purchaser of textiles just as it has served the manufacturer and chemical tests combined with physical tests can be interpreted to classify a piece of goods in terms of wear. It is better to know the history of the fabric, by which is meant the kinds of fibers put into the yarn and just how they were placed there, but this information is not readily available and therefore other tests must be devised.

As regards fibers, the careful buyer wants to know most of all whether the goods is as represented. This involves knowledge as to what trade terms mean and the significance of the presence of various kinds of fibers in mixtures. In some cases the weave is very important and some one of these days research will have provided us with information regarding the relation of fibers and weave to service. Knots are to be avoided, for they lead to early damage and failure of fabric. Often, the resistance of the goods to mud spots is important and whether or not it is resistant to perspiration should be known for some classes of materials, such as linings. The fastness of the dyes to fading and to washing nearly always is a factor. Then one would like to know how it will wear, provided one is of that number who put service on a par with or a little above style. The merchants claim this number to be small, although in this the ladies say they are slandered and that a large number are always ready to purchase high grade merchandise in conservative models.

That all these points and others cannot be predetermined in a scientific manner is in part due to the small use of science which the textile industry has made. The industry is one of the world's oldest. Improvement in mechanical appliances has been of the highest order, and yet a host of fundamental investigations remain to be made. This means that, among other things, we still have to perfect rational accelerated tests for some qualities that will tell us directly and in advance of purchase what we wish to know about a piece of cloth.

A start can be made on the problem by learning the behavior of pure fibers under various conditons. This will give characteristic and constant properties by which they can be identified and perhaps separated. It will be helpful to divide them into those coming from the vegetable kingdom and those derived from animals. The vegetable fibers give the world more than 95% of the fabrics used for all purposes, and in many parts of the world, where population is densest, little cloth but cotton is worn. Cotton and linen are so similar in properties that they

can be distinguished with certainty only when the microscope is used. Indeed, if testing facilities were to be limited to a single instrument the microscope would be chosen, for in the hands of a moderately experienced observer it can be made to tell almost the whole story of fabric composition. To have even considered the microscope in this work a few years ago might have been absurd; but to-day nearly every high school has such an instrument, and the number familiar with its use and power is greater than those who had even seen one a short time ago.

Under the microscope cotton looks like a twisted, narrow ribbon. If examined throughout its length it will be found pointed at one end and with a broad torn base at the other where it was detached from the seed. The twists have to do with the cohesion of the fibers in the thread, and so, for extra strength, only the long fibers with many twists are employed. The threads for cords in cord tires are an example. In other threads short fibers can be used with the longer ones. Abroad, cloth has been produced from cotton fibers which are shorter than those considered spinnable in America.

Linen, the descendant of the fibers separated from rushes and reeds by our prehistoric ancestors, has a faintly jointed or bamboo-like structure. The individual fibers are much longer than those of cotton, and this is one reason why well spun linen thread is much stronger than a cotton one of equal size.

Both cotton and linen resist a weak boiling solution of alkali such as caustic soda; but they can be dissolved in acid. Some have thought the degree of solubility in strong sulfuric acid could be used to tell cotton from linen; but the method is unreliable.

While our principal vegetable fibers are alike in many respects, we never confuse the two animal fibers silk and wool. We need no microscope; but through it raw silk is seen as a structureless material made up of the two transparent fibers cemented together as they come from the two spinnerets on the head of the silkworm. These fibers are literally many yards in length. Wool fibers are covered with scales which are more

prominent on new wool than on reworked wool. It is to these scales that wool owes its felting properties. Silk and wool dissolve quickly in solutions of caustic soda; but they resist acids.

With these few facts in mind one can at least learn whether the goods is really all wool or all silk and, as we shall see, one can gain some idea of how the various fibers are used together. A small sample from the piece or from the inner seam of a made up garment is enough. A small enameled pan is filled with a solution of household lye made by putting a tablespoonful into a pint of water. This is brought to a boil and the sample boiled for fifteen minutes, during which time hot water is added to keep the volume constant. Whatever remains of the sample is neither wool nor silk. This residue should be washed and dried for examination.

Should there be any doubt in one's mind as to wool being the fiber that has dissolved, just add a little sugar of lead (lead acetate) solution. This compound, sometimes used to fix the color in cloth before washing, will react with the sulfur naturally present in the wool and give a gray or black color or perhaps a dark precipitate or sediment.

In a "union" cloth it used to be customary to use cotton warp — the threads running lengthwise of the goods — with a wool filling or woof, as the crosswise threads are called. Nowadays any combination may be expected. Look at the residue from the lye boiling test. If the recovered cotton threads are in a tangled mass, it is probable the cotton ran in but one direction of the goods or was spun with the wool. Sometimes a cheesecloth-like piece remains, indicating that around each cotton foundation thread there had been spun wool either to add warmth, or to improve appearance, or to deceive. Incidentally, such a fabric fills a valuable need. It is warmer for the wool and stronger for the cotton than would have been the case had either fiber been used alone. But one wants to know what one purchases.

In instances where a nap is desired, as on a blanket, this may be secured by spinning wool with the cotton and then using

mechanical means for combing up this nap. This process tends to weaken the fabric, leading to an early break.

The laboratory applies the lye boiling test and calls it "boiling out" the sample. If the quantity of each fiber is to be found a delicate scale is used. The sample is weighed and the residue dried to constant weight. From these figures the percentage can be determined. Dyes may be used to distinguish these fibers, for acid dyes on cotton are not fast even to mild washing. If the cotton or linen is to be removed from the sample, rather than wool or silk, the sample is saturated with a very weak solution of sulfuric acid, dried at the temperature of boiling water for an hour, and then gently rubbed between the palms of the hands. The cotton and linen will be charred ("carbonized") and will rub away from the animal fibers.

But what of artificial silk? While simple tests have been developed for telling artificial silk from real silk, a chemical test is more reliable. If the fiber under examination is heated in a dry test tube, moist neutral litmus paper over the mouth of the tube will tell the story. Litmus is an organic, natural product which has the property of changing color according to whether acid or alkali is present. Chemists call it an indicator because it does indicate which is present. Blue means alkali, and red, acid. Neutral litmus paper can be used for either test and is more sensitive when moistened, preferably with distilled water. Real silk gives off ammonia which turns the paper blue. The artificial silk gives off acid fumes and the test paper becomes red. There are other tests to distinguish between these silks; but they are either complex or not so good as that outlined above.

What of other fibers? These may be many, and in general the merchant should be on the watch for them and either prevent his guarantee from becoming a liability by keeping them in their proper places or give the customer full information. Not so long ago, a towel supply company bought seven hundred hand towels which were washed to remove sizing and improve their absorption properties before going into service. Every single towel failed in the first washing because bleached hemp

had been used for the filler or woof. This fiber has no strength when wet and so fell apart during laundering.

There have been several samples of jute and cotton cloth on the market, and then there is the case of the rag rug which fooled an experienced buyer. This lot of rugs had the usual assortment of colors; but there was a large percentage of brown which, on the whole, was very pleasing. Washing began to show up the inherent defects which were traceable to the jute. This fiber formed the largest part of what had been sold as an all cotton rag wash rug, being the core of every filling strand and having the colored cotton strips wound around it.

Some of the other fibers include ramie and two more recently developed commercial fibers called "solidonia" and "posidonia." Solidonia is made from China grass and is somewhat similar to ramie. In Germany a long, fine, soft and curly fiber has been secured by a secret process. The fiber looks very much like wool, until placed under the microscope, and it mixes very readily with wool. It has been used in woolens and in underwear, some experts claiming that it prevents shrinkage and is therefore a valuable addition in the manufacture of underwear. Solidonia has also been used in producing linen substitutes, in knitting hosiery, etc.

Posidonia is another vegetable fiber being made from a seaweed dredged near Australia. After washing in fresh water this weed is treated to convert the harsh, brittle fiber into one which is elastic and springy. While at present this fiber is considered more for carpet manufacture than for clothing, still it can be spun with wool and has been used with it and with shoddy. The cloth made from such yarn resists creasing remarkably well, has good strength and appearance.

Those responsible for these developments have directed their science toward jute and even old jute rags which are considered nearly worthless in most places. From this exceedingly cheap raw material chemical processes bid fair to win a fiber which can be spun by the methods applied to worsteds or woolens. Serges from old jute rags and cloth half jute and half wool have

puzzled many an experienced textile man. The wool in this material is from sweaters, certain qualities of wool rags, woolen hosiery, etc.

It seems evident that these new developments are of real importance and it would be better to acquaint ourselves with the merits of these economically valuable fibers rather than to spurn them untried. The only sound objection comes when their presence is covered and misinformation, if any, given. But does it not seem reasonable to expect our merchants to know what they buy and sell? To impress this upon them the ultimate consumer must be sufficiently familiar with fabrics to ask intelligent questions and in turn listen to sound explanation.

But these are not all the pitfalls. Faults in construction, those factors which cause most of the "seconds" to be made, are just as troublesome. The average shopper cannot be expected to discover them all; but she can know that a difference of a few threads per inch may account for a bargain price and also for a weakness of the cloth responsible for early failure in service. Some of the more reliable houses refuse to merchandise percales, sheeting, and other standard materials with less than a given number of threads per inch, that number having been found from both laboratory and wearing tests to be the least that will have reasonable strength for the service of cloth in a given class.

These tests are now based on tensile strength and resistance to bursting. The first is determined by measuring in a special machine the energy, in pounds, required to break a standard size strip. Moisture and temperature have a direct influence on the strength of cloth, as will be obvious when one remembers the many kinks in a single cotton fiber. When very dry, the fiber breaks much more easily at these points. Strength tests are therefore made under standard conditions of temperature and humidity. In some methods a strip is prepared by removing a thread at a time until just one inch in width remains to be held between the jaws of the machine. This is the strip method. The "grab" method is considered less accurate.

The bursting test is applied with the apparatus used to determine paper strengths. The sample is held firmly between two metal circular rims while a rubber disk is forced against the center by air pressure. A dial records this pressure and the hand remains stationary when the break occurs.

These are obviously methods to be used by the manufacturer and the merchant; but one can obtain some idea of strength in other ways. For instance, see how easily the cloth may be torn in each direction. Then hold it firmly and see to what extent it gives when the thumbs are pressed against it. Tender threads, cloth in which an excess of short fiber has been incorporated, and poor weaving, often show up in these simple tests.

Weave is not a difficult thing with which to become acquainted. A plain weave is one in which the woof, or filling thread, goes over one and then under one of the warp threads. No two adjacent filling threads cross on the same side of a warp thread. This makes the strongest cloth. Beauty is added, but strength is sacrificed when the satin weave is used. It gives a smooth surface which reflects more light and makes fancy patterns easily possible. In the satin weave the filling thread passes under one and then over four or more warp threads. In other fabrics long "float" threads are used, and these may cross as many as eighteen or more warp threads. Some pile-like (velvet-like) finishes are in reality float threads.

This loose weaving leaves unsecured threads which slip and rub and soon break. If they are cotton the break comes sooner because of the shorter fiber making up the thread.

It would seem wise, therefore, to refrain from buying cotton fabrics in which patterns requiring long floats are woven. One would also seem to have a right to expect only long fiber cotton to be used in tightly spun threads if cotton float threads are used and these floats should be kept comparatively short.

The importance of weave is illustrated by bath toweling, commonly known as terry cloth. This is a loop-pile material made up of two systems of warp threads. One of these goes to make the ground fabric while the other furnishes the pile in the

form of loops on the surface. The excellence of the cloth depends upon the number of filling threads that are inserted for each cross row of loops and these may be one, three, four, five or six. This determines the firmness with which the pile is held in the ground fabric and the extent to which "pulling" may be prevented.

But we must realize that *all* fabrics cannot be of the highest quality in *every* respect. There are certain to be practically unavoidable faults if human hands are involved in manufacture, and it is well known that all worsted cannot be made solely of new long fiber wool. There simply is not enough of it. If it were not for reworked wool and cotton much of the world would go cold or naked. One should recognize these facts and accept intelligently the correct information which your merchant should be able to give. It may be that when we overcome long standing prejudices with knowledge the merchant will be more willing to tell the whole truth about his wares.

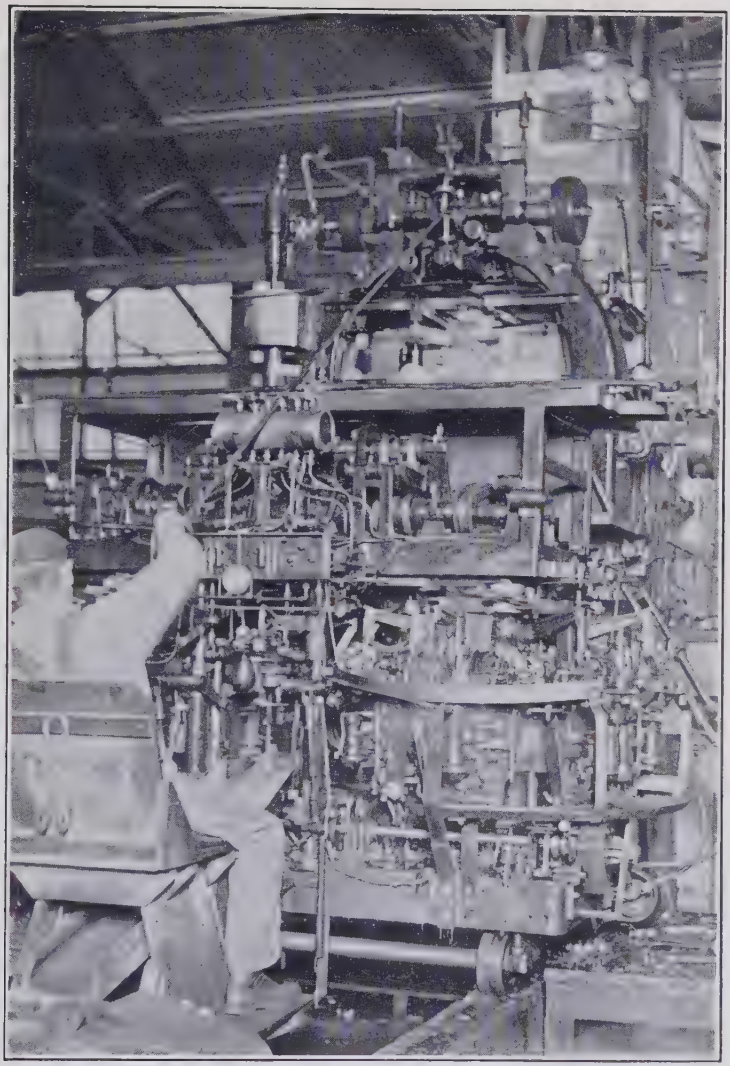
There are many other things which we should like to know in advance about the quality of the fabrics which cost such a large percentage of our income. Science is striving to find a way to supply such information. Particularly, we want to know the relationship between the way a fabric is woven, the composition of the goods, and the service it will give. Manufacturers frequently test their product by having operatives and others wear it; but that is too time-consuming. By dividing a problem into its factors and solving these one by one, research is sure to find the answer.

Chapter VI

DECORATION — ESCAPE FROM MONOTONY

There can be monotony in the scenery, in one's work, indeed such a sameness of impressions in whatever field we find ourselves that no arguments need be advanced on behalf of decoration or any other plan that will introduce pleasing variety. There is an advantage in a great multiplicity of sizes, textures, shapes and colors, in the things all about us. The mountains are never so monotonous as the plains, for the plains present a greater regularity. A forest becomes more attractive when the trees are of different species, thereby introducing varying shades of green and foliage, or where the trees are of different heights. When things become too standardized we lose our interest in them, and we know it is not the average man that attracts notice and is in the greatest demand, but rather the unusual, out of the ordinary individual. If it can be shown that chemistry in the world's work has contributed something toward relieving the world of monotony, it is something of which we can be justly proud.

The variety of building materials available to-day makes it possible to go to the other extreme, and many cities show the need of a supervising architect. The proper use of this variety of building blocks, however, is responsible for the very attractive appearance of the modern structure. Chemistry has made a greater contribution than may at first be realized. Stone is doubtless among the oldest of the building materials, and in its carving and finishing to size and shape the artificial abrasives of the electrochemist find a wide application. When a young man, Acheson heard the remark that the world badly needed a good abrasive. He decided to attempt to supply it. He had a theory that clay could be so worked in an electric furnace as to give the desired product. He began his experiments with a small



AN AUTOMATIC ELECTRIC LAMP BULB MACHINE.

This one of the mechanical marvels, producing glass bulbs at such rate as to reduce materially their cost to the public. The chemist and physicist have a share in this accomplishment through the provision of glass having such physical characteristics as to make this operation a possibility. (Courtesy, Corning Glass Works.)

iron pot, which he attached to one lead from a dynamo and, after filling it with a mixture of clay and coke, inserted one end of an ordinary arc light carbon in the mass. The coke acted as an electrical conductor and current was passed until the clay in the center had been melted or sintered. The experiment was disappointing; but by chance the investigator saw a few bright specks on the end of the carbon electrode that had been thrust in the coke-clay mixture. These proved to be what was wanted, and from this beginning there has been developed a race of artificial abrasives of more uniform quality than the natural emery or corundum, capable of being made of the desired hardness, and for a great majority of purposes superior to natural abrasives. These crystals are incorporated with various clays which act as binders and after baking form the cutting wheels and grinding or polishing surfaces so largely used in working our granite, limestone, and marble for structural purposes. The tooling, which consists of numerous parallel lines on the face of stone, formerly cut by hand is now cut by power driven gangue wheels.

The production of modern building bricks depends to such an extent upon science that associations of manufacturers maintain research fellowships in some of our leading educational institutions. The texture and color of this ceramic ware, together with the art of properly combining the various bricks to make a wall, give a range of surfaces which are anything but monotonous. Mineral pigments are the ones employed to color brick, terra cotta, and tile, and these chemical compounds may either be found in the clay mixtures employed or may be added at will. Account must be taken of a change in color which will be due to both the mixture with which it is to be placed and the temperature at which it is to be heated. In fine pottery, the employment of a glaze adds another factor to consider in obtaining the exact shade wanted in the final product. These glazes range from common salt (sodium chloride) to complex silicates, for glazes ranging from great luster to a dull mat finish are wanted.

In the decoration of ceramic ware, which includes fine China and porcelain, a special kind of color must be prepared calculated to withstand the treatment characteristic of the ceramic art and still capable of giving very fine gradations in tints and colors. The metallic elements themselves play a large part and may be introduced in a finely divided state as a pigment in a vehicle of some oil or may be applied in a solution so designed that after firing in the reducing atmosphere of a furnace the metal will remain on the ware. Gold is, of course, the chemical element in greatest demand for such decoration.

The employment of metals in building operations adds further variety to the scene. Much of the metal is used from a purely utilitarian standpoint and becomes gutters, downspouting, window casements, and roofs. Where desirable, these may be so designed as to add beauty; but too often no attention is paid to the possibility of improving the appearance of a useful object and the beautiful things are left with no real work to do. We see to-day bronze lamps, doors, and stair rails which compare very favorably in design and execution with the work of the ancient craftsmen. In some localities where an artist lived of old there may be found many relics of his handicraft still in a good state of preservation, and as there seems to be no present source for this material, especially in the locality, the lecturers on sight-seeing cars refer to the grills or other work as a lost art. As a matter of fact, the cost of producing articles that must be hand made has advanced to the point where such art is not encouraged; yet modern examples prove that the skill has not been lost and it is largely a question of what the customer is willing to pay.

A great many objects must depend for their decoration upon surface coatings applied after they have been fashioned. Even the metals that are turned or cast are frequently given a coat of nitrocellulose or similar colorless transparent lacquer which protects the surface from attack by the hydrogen sulfide and other sulfur compounds in the air. This is especially true in cities where industries give rise to the burning of much bituminous

coal usually high in sulfur. Many a housewife has wondered how the jewelers manage to keep their large stock so bright and free from tarnish, not realizing that the chemist has prepared a special lacquer for such flat ware which when applied may sufficiently protect the article for the entire time it is in the possession of the retailer.

While nitrocellulose lacquers are the principal ones used in this field because they are air drying and easy to apply, there are a number of other lacquers also made both to decorate and protect. Until recently it was customary to prepare a lacquer, with which to finish scientific instruments, from the best shellac and absolute alcohol. By absolute alcohol is meant that which is free from moisture and is really all ethyl alcohol. After the shellac was dissolved in this alcohol, the solution was allowed to stand for many months with frequent shakings, during which time physical and chemical changes took place, giving a product considered far better than a freshly made shellac solution. A few drops of oil per gallon of lacquer helped make it more elastic. It was applied with a hand brush in very thin coats between each of which the lacquered part was passed quickly through the flame of a Bunsen burner to facilitate driving off the alcohol solvent. Colors were obtained by adding certain dyes or by changing the composition of the brass. Hard red brass is made so by the addition of copper and tends toward the red, while one with less copper but more zinc will be found of a lighter shade. Sometimes this brass has to be used in combination because of physical properties, and then the problem was one of coloring the shellac solution with some alcohol soluble dye so that the instrument might have a uniform appearance. But having been made with alcohol, such lacquers were easily marred, spotted, or sometimes removed by the small amount of alcohol in other solutions that might remain on the hands of the investigator. It is difficult to have workmen change from a type of lacquer they have used for years to the lacquers made by chemists according to new methods and principles. Scientific resins of the Bakelite type have come to be used, for after

baking they are practically insoluble in such reagents as one ordinarily finds in the laboratory and certainly many of those which may be on the hands of the operator. This same type of lacquer has found general application in the metal industries and to-day we find it on brass beds and lighting fixtures, as well as scientific apparatus.

A finish is more resistant if it has been baked in place. The baked japans and enamels are noted for their satisfactory service. The gums employed in them will not dry down to a hard surface, but must have the solvent driven out by heat and the residue thoroughly dried or baked in the enameling oven. The use of this baked enamel has extended to such large pieces of work as entire automobiles for which specially constructed electrical ovens are provided. The solvents employed may be benzol, naphtha, or other volatile organic solvents, which readily take fire under proper conditions of heat and mixture with air in the ovens. This was especially true of electrical ovens where the vapors could come into contact with the heating units. One of the great electrical companies primarily interested in disposing of electrical equipment undertook to devise a lacquer which would be an emulsion in water and not a volatile solvent prone to ignite at the slightest provocation. Such an emulsion in water was made, was found to spread satisfactorily over the metal work dipped into it and to bake into a satisfactory, attractive, protective and decorative film. This eliminated the hazard always present where volatile organic solvents are employed.

Our greatest spot of color on the landscape beside the green of the vegetation is due to the use of paints and varnishes in giving a protective coating to the structures. The pigments are natural ores ground very fine or perhaps chemically produced. These colors are ground in linseed oil, the mixture is later thinned with turpentine or mineral spirits, and a dryer to accelerate the drying tendency of the oil is added. This dryer is made with the chemical elements cobalt, lead, or manganese.

The interesting thing about pigments is the fact that if a

color is to be used, say, chrome green, the amount required can be greatly reduced if the material is so ground that it is much finer than a cheap white lead pigment, and if the relative size of the two particles are kept uniform, the smaller ones will become packed over the large white ones. This gives a body of green which appears green but which by weight may contain a larger proportion of the white lead material than of the green pasted upon it. The principal white pigments are white lead or lead carbonate, zinc in the form of oxide or a chemical product, lithopone, which contains approximately 30% zinc sulfide and 70% barium sulfate. This is made by chemical precipitation and lithopone lacks a wide application not only in interior wall paints, but particularly where hydrogen sulfide is present. This would darken lead paint, but makes little impression upon lithopone. Antimony oxide and titanium oxide are other white pigments. White lead has been known since before the Christian Era, for Theophrastus has described a method in use for preparing white lead more than 300 years before Christ.

Metal powders have a specific use in paints. Zinc dust is used as a pigment in anti-corrosive paints and aluminum powder or bronze is well known indeed. These metal pigment preparations are particularly useful in protecting iron and steel. It has just been shown that oil storage tanks painted with aluminum paint last two to three times as long as those painted in some of the common colors which absorb all the heat. This tends to raise the temperature and the more volatile portions of the contents escape.

The standard type varnishes are produced from fossil resins found principally in the Orient and the tropics. The resinous resin is blended with heat treated drying oils. Here again turpentine or mineral spirits or alcohol may be used as a thinner. Materials which behave as catalysts in causing the varnish film to take oxygen from the air more rapidly are also used in varnishes.

The production of varnishes has sent the chemist to all parts of the world for raw materials. As a result China wood oil is

being used in increasing quantities. Among its advantages may be numbered failure to change color when wet. This oil, therefore, enters into many of the varnishes advertized to withstand water. The resins preferred are the hard fossil resins, all of which are highly acid. These are limited in supply and are not so resistant to water and alkali as the so-called ester gums made by combining the highly acid resins with a substance like glycerine to form a neutral product.

The chemist has supplied an entirely new solvent in furfural, which may be made from corncobs, but is actually being produced commercially from oat hulls. Furfural is a good solvent for dry paint and varnish, and finds employment as a paint remover. Furfural is also said to be a good solvent for the new types of nitrocellulose lacquer widely employed for the finishing of automobiles.

Such solvents as amyl acetate, butyl acetate, ethyl acetate, anhydrous alcohol, diethyl carbonate, ethyl lactate, and butyl propionate have helped to revolutionize the lacquer industry. The new types of low plasticity lacquers combine the advantages of high solid content with such low viscosity as to insure satisfactory application. Plasticisers, of which there are many, are employed and the mixture incorporated with solutions of resins, after which it is pigmented to produce the colors wanted.

In this achievement it is interesting to note that the body of the lacquer is nitrocellulose, made from American grown cotton and that the solvents are prepared either by the fermentation of corn or molasses, so that this sensational development in lacquering involves only self-contained, American sources of supply.

Recent work has shown that the colors of radiators not only have a psychological effect, but influence the economy of operation. Tests show that bare radiators or those coated with dark paints or even with aluminum or bronze paints give the least radiation. It is the white or light tinted paints and those with a flat surface that give the greatest radiation and should therefore be used where economy is practiced.

Enamels are made by grinding pigments in varnish. Their smooth, glossy, hard surface indicates them for a number of special applications.

Some types of wall coverings involve paints or their first cousins, the inks, but they are not applied in liquid form. The production of types of wall coverings such as cloths and papers, which may be embossed, have special surface treatments and otherwise made unique, involve not only chemical control but the use of particular colors for intricate patterns and a fine blending of numerous reagents. The printing of wall paper is similar in many respects to the printing of any other material where engraved rolls are used, though for special purposes hand block printing may be employed. This consists in applying the color in the form of ink to an engraved block, usually of wood, with which the pattern is carefully transferred to the paper surface. Where surfaces like oatmeal finish are to be obtained on wall paper this material can be added in the beaters or put upon the surface as the paper pulp comes upon the paper making machine. The days when the paper hanger made his own paste from flour and water are well nigh by, for now the chemical laboratory supervises the manufacture of starch and dextrin pastes. They are more serviceable and are capable of being prepared with more uniformity than the old style mixtures.

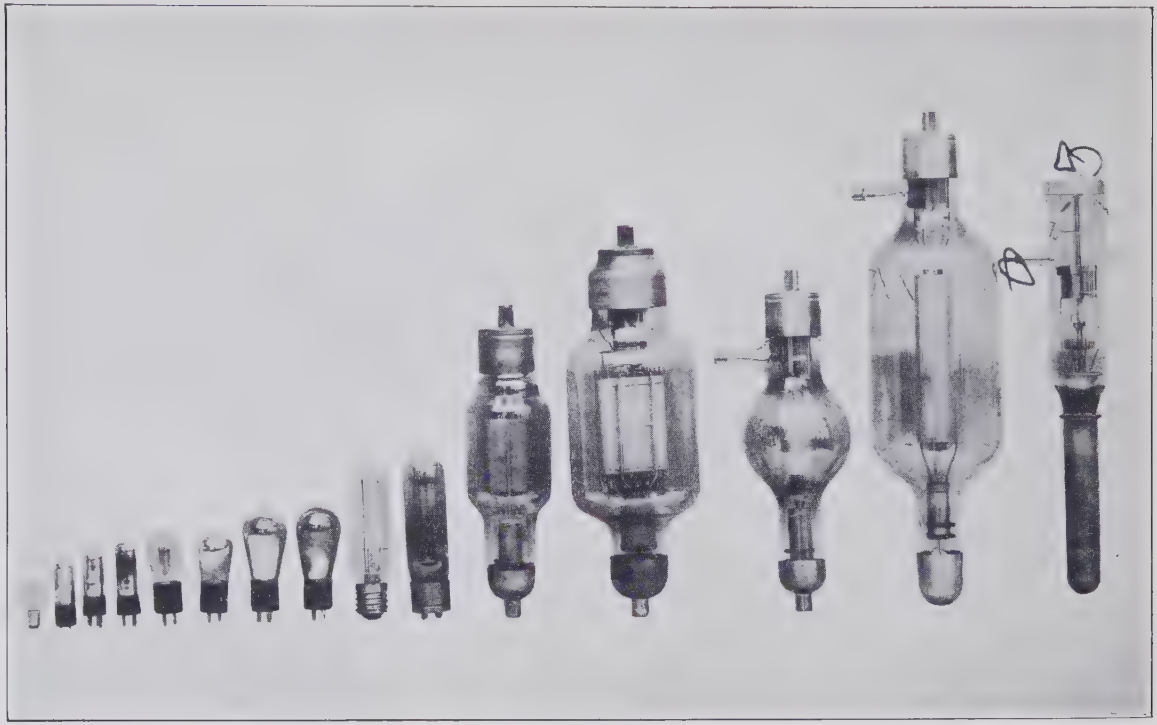
The floor coverings, which both serve and decorate, may be rugs dyed with synthetic organic dyes or one of the newer materials offered to replace the carpet or rug capable of accumulating much dust and absorbing much that is detrimental. Linoleum has held the center of the stage for a long while but of late is threatened by rubber tile. The latter is made in as great a variety of patterns and colors as could be wanted. However, linoleum and materials of a similar sort have long performed a valuable service. As the name indicates, it is made from linseed oil. Wood flour, cork and other fillers form with the oil a mass which is pulverized and treated to produce a mixture that is then placed upon a heavy cotton fabric usually of jute. After being pressed under hydraulic pressure, the treated cloth, in

great festoons, is taken into heated passages called stoves, to dry and is then ready for service. Sometimes linoleum is printed to give design and added color or it may be inlaid, in which process the pieces composing the pattern are moulded and then assembled before pressing to form the commercial product.

Rubber tile may represent a new outlet for used rubber. A market is needed for this otherwise waste material, and with the increase in the cost of crude rubber, rubber flooring may have to compete with tires for a part of this raw material in future.

Just as the walls of stone, brick, or terra cotta are laid up with cement rather than a lime mortar, if a permanent work is desired, so also the terrazzo floor is laid in cement, the other constituent being various sizes of aggregate usually of some hard marble. There have been instances where soft stone was used to form the terrazzo type of floor only to have this stone wear away before the Portland cement began to show signs of service. Such a floor not only wears unevenly but is dusty and of poor appearance.

Glass is effectively used in decoration and to-day; after hundreds of years, the mirror is still valued for its decorative qualities. There was a time when all mirrors were made with mercury or quicksilver; but this is not the modern practice. To-day the best mirrors are made by chemically cleaning the surface of the glass and then precipitating upon it metallic silver from a solution to which a reducing agent is added just before the solution is applied to the glass. Most of the silver does not deposit on the glass but may be recovered in the form of a metal so finely divided as more nearly to resemble gray mud than the shiny metal we know so well. Several coats may be required to produce a film satisfactory in continuity and thickness. Sometimes particles of silver precipitate upon a surface before a film is formed and this gives rise to a pinhole rather difficult to cover when once it has been formed. The concentration of the solution and the temperature at which the work is done are important factors in the production of a good mir-



A Group of Radiotron Tubes.

Showing a few of the many types of vacuum tubes that have been designed for radio broadcasting and receiving. The vacuum tube is an excellent example of what can be accomplished when chemistry and physics join forces. Many believe that we have only begun to realize the potentialities of the vacuum tube in science and industry. (Courtesy, General Electric Co.)

PLANT OF
REFUSE BURNER
BORN OCTOBER 1
ED JULY 4, 1924.
very day during my life of sixteen years
consumed daily 500 cords of
or a total of 2,688,000 cords.
cost $75,000, but my fire has
$1,344,000 worth of what was formerly
considered waste.
The complete utilization of the
refuse in the manufacture of paper has
my fire forever extinguished.

Refuse Burner.

The Great Southern Lumber Company, in causing this legend to be painted upon its refuse burner, has paid tribute to the contributions of chemistry in the elimination of waste. (Courtesy, Great Southern Lumber Co.)

ror. If dilute solutions are employed at low temperatures, many coats may be needed to produce the specified thickness; but the chance of avoiding pinholes and other blemishes is greatly increased. By choosing certain temperatures and solution concentrations, silver can be deposited in so hard a film that it cannot be removed by cutting without actually scratching the glass.

Not content with silvering the mirror, the chemist may go further and deposit electrolytically a film of hard copper over the silver and this in turn may be given a coat of lacquer.

It is obvious that if weak solutions are used the film is built up very gradually, and this is the basis of one-way glass. It is possible so to silver a mirror that on one side it appears as such; but, if the observer is in a darkened room facing the mirror which is against the light, he will get not a reflection but will be able to see through the silver film. In other words, the silver particles are close enough to give a moderately satisfactory reflection on one side and yet far enough apart to enable one to look through.

The use of leather, tooled and colored, involves chemistry in the coloring and in the method of fastening it in place. Of course, tanning the leather in the first instance is a chemical process; but on that basis it would not be difficult for an enthusiast to show that nothing that is worth while is other than chemical. Rubber is also used for decoration and is sometimes vulcanized in place for this purpose. A case in point is covering the modern binocular. By using a photograph of some particular type of leather taken as a pattern, a metal plate can be made and hardened so that under pressure it will impart to the rubber the pattern of the original leather. By following a special procedure these sheets of rubber can be made to adhere to the metal body of the binocular and then vulcanized in place. The result is a covering far more efficient in protecting the binocular and of greater wearing quality, having the appearance of whichever type of leather is thought most suitable for the article in question. Whether rubber latex, the sap of the rubber tree preserved in

ammonia, will be used for a covering remains to be seen. It has many advantages from the standpoint of protection afforded but may not be decorative.

When we consider the range of colors offered by the various metals, the difference in appearance obtained by surface treatment such as polishing and sandblasting before plating, and the further colors obtained by oxidation and other chemical reactions carried on upon their surface, it will be seen that the electroplater's art is indeed an art. In electroplating the purpose is to give a base metal an adherent coating of another metal which may be for protection, for decoration, or for deception. Many of the metals are capable of being deposited electrolytically, and as has been noted in another chapter this method is used for refining. The general principles of electroplating seem indeed simple, for in order to deposit copper it is only necessary to have a suitably formed plate of pure copper to serve as the anode, a place for attaching to the other electrode the object to be plated, and a solution of the metal through which the electric current may guide the electrons from the dissolving anode to the cathode which is to be plated.

Copper plating usually employs a cyanide copper solution for plating on steel followed by an acid copper bath if very thick deposits are to be obtained. The acid copper bath cannot be used directly for iron or steel, as the iron tends to dissolve and produces a non-adherent film on the copper by simple displacement.

Nickel is more often used for plating than any other metal. Fortunately, nickel does not tarnish readily and the film is hard enough to resist a surprising amount of abrasion. The tarnishing that is sometimes observed is not due to any inherent weakness in the nickel, but to the fact that the coating is not continuous just as the coating of silver on glass in the production of mirrors is likely to fail in the same respect. The average thickness of nickel plating is only one or two ten-thousandths of an inch.

When cobalt was produced in Canada, much useful research

was done in ascertaining the conditions under which it could be used for plating. Cobalt and chromium are both important because their films are very hard, and of the two, chromium is the hardest. It produces the hardest film of any known metal. Since cobalt steels have come into vogue, the efforts to use it as a plating material have largely subsided and the research workers are turning their attention to chromium. A commercial method for chromium plating has rewarded their efforts.

Zinc and cadmium, lead and tin, silver, gold, and platinum all are used in plating. The principles are the same; but the solutions vary greatly in composition and the current density, by which is meant the amount of electromotive force for some convenient unit of surface to be plated, must also be regulated according to conditions. Brass is extensively used particularly for lighting fixtures and for building hardware. If there is no misrepresentation in sales, this practice might be encouraged. At one time close-plating was practiced. This was a mechanical operation in which a thin sheet of the metal to be applied was formed to exactly cover the base metal to be plated and soldered into position. The time and labor required to close-plate a complicated bit of base metal is one of the disadvantages.

If metals can be taken from the anode and placed upon the cathode, it is obvious that the process should be reversible, and such is the case. This process is employed in certain types of deep etching where that part of the cathode to be left untouched is covered with a resist material having some organic compound as a base. In this way not only may a design be placed upon a sheet, but by continuing the plating process, the sheet may be perforated or dissolved away where left unprotected by the resist material.

Obviously, electroplating can be done successfully only when the material to be plated is an electric conductor, thus attracting and guiding the metal to be plated. Sometimes a nonconducting material is offered, as, for example, the baby's shoe, many of which have been metallized as keepsakes.

Such an object can be coated with graphite, which is a suffi-

ciently good conductor to enable a thin copper coating to be applied, after which other metals may be superimposed as desired. A gentleman with a peculiar streak of humor once took the trouble to have his appendix gold plated as a watch charm. The appendix was first dehydrated according to the ways of the biological laboratory in successive baths of increasing strengths of alcohol, after which it was impregnated with celloidin. This in turn was coated with graphite and the rest was easy. One of the secrets in the deposition of metals is the art of metallizing flowers. Roses and other beautiful flowers are sometimes offered in a metallized condition, a product truly admirable secured by a secret process.

While the best results are obtained when the entire object is electroplated, it sometimes happens that small blemishes on plated work or a scratch in service is all that requires restoration. For such purposes plating powders may be made, consisting of chemical salts of the metal wanted in combination with reducing materials, which, when the mixture is applied, cause the metal to deposit out, thereby covering the blemish.

It is obvious that the deposition of metal films by electroplating adds something to the size of the base metal piece; but it was not until recently that it occurred to platers to use this process in building up castings or machined parts that failed to show specified dimensions. Where the errors are not too large and the service is one that can be performed by a member thus increased in size the plating process finds utility.

There is a continual effort to avoid monotony as the changing styles testify. These are styles not alone in clothing but in art, architecture, decoration, design and every other human expression. All involve changes and variations in materials and that means chemistry at work.

Chapter VII

METALS THE MASTER

It is quite probable that the metals were the first chemical elements utilized as such by the race. It seems certain that they have played a vital part in helping man out of the jungle, and it is not difficult to imagine the elation that one of our primitive ancestors must have felt when he realized that in some crude bit of metal he possessed an inestimable advantage over his adversary. Perhaps the introduction of metal shod weapons into warfare was considered just as unsportsman-like at the time as was gunpowder at a later date by the knights in armor. There was probably as much resentment against the use of such weapons as the navy feels toward the airplane or as the military man of the old line voices against chemical warfare.

It is quite unlikely that the gold of Tutankhamen's tomb or of King Solomon's temple could ever have been produced by the ancients, if they had been compelled to work the deposits now available to us. It is believed that these treasures of metal must have resulted from finding bonanzas of native metal which could be worked by hammering and similar mechanical methods of refining. While the earth may still hold native or free metals in considerable quantities to be revealed to some succeeding generation, our experience thus far has been that, as we draw upon these natural resources, we find it necessary to devise new chemical methods for the separation of the metals from the ever leaner ores which must be used. This is not to be taken as meaning that we no longer have rich ores at our disposal, for many mines still produce ores rich in metals both precious and base. However, the rate at which we use metals has compelled us to consider the commercial use of the leaner ores, and fortunately science has been able to keep pace with

new requirements. The race has used within the last generation more metal than in the entire previous history of the world, and it is not likely this could have been done but for the contributions of science. "Just as our increasing ingenuity enables us to secure natural products in ever increasing quantities from sources that would have yielded nothing to our forefathers, so those who follow us must ultimately rely on science to produce substitutes for our natural products." It has been stated that in the days of Hiram, King of Tyre, the Rio Tinto mine in Spain was a source of much of the silver he used, but that it required 40,000 workmen a year's time to produce three tons of the metal, and undoubtedly the craftsmen of King Solomon produced the metals for the temple at a cost impossibly high for modern industry.

There has been little change in the methods of mining in the last several hundred years, as will be observed by comparing the writings of George Agricola, so ably translated by the Hon. Herbert and Mrs. Hoover, with accounts of modern mining methods. It is true that many mechanical improvements have been made and that more recently machinery has been provided actually to do work heretofore accomplished solely by hand, but the principles underlying it all have changed but little. Modern explosives have been added to lower the costs; but the principal gains have been in the application of chemistry to the problems of metallurgy.

In the chapter discussing modern communication reference has been made to the electrolytic method of refining copper. Attention may be called to the cyanide process for the extraction of gold, this process being in almost universal use to-day. Because of the higher price of potassium cyanide used as a solvent for the precious metal in this process, research was undertaken some years ago and it was discovered too late to save vast quantities of precious potash that sodium cyanide is equally efficient and much less costly. The methods by which nickel, and indeed all the ores, are refined to-day are either frankly chemical methods or depend upon chemical control.

Zinc offers interesting problems. It is still treated in small retorts arranged in great banks, each retort holding a few pounds of the ore and yielding a few tablespoonfuls of spelter per charge. Much money has been spent to increase the size of the unit and at least use larger retorts; others have worked upon continuous processes, but the small earthenware retorts continue to give the greatest efficiency. Much hand labor is involved, retorts break, and a novice looking on feels sure that something could be done to make matters better, but thus far the old reliable method has held its own.

The blast furnace familiar in nearly every industrial community, whether ore is treated or the furnace used to melt scrap, depends for its efficiency on the proportion of flux such as limestone, and coal or coke which is mixed with the iron ore, as well as the proper air supply, all being based on the chemical requirements. Some scientists believe that in blast furnace operations and in steel making it would be a wonderful advantage if the air could be enriched with oxygen. It is thought that the slightly higher temperatures that could be obtained if more oxygen were available would help to obtain superior metals probably freed from occluded gases and stripped of traces of impurities objectionable for some uses. The plan would involve the production of oxygen through liquefaction of air, necessitating a good market for the hydrogen and necessitating efficiencies in the use of mechanical power required for compressing that so far have not been realized on a commercial scale. Within the year such rapid developments have been made in processes requiring hydrogen that interest may be revived in this metallurgical problem. These hydrogen-using processes are the syntheses of ammonia, of methanol, and of petroleum-like bodies using carbon monoxide and hydrogen in the presence of suitable catalysts.

As has been noted elsewhere, steel, if of high quality, has been made by a chemical process or, more strictly speaking, under chemical control, for the percentage of carbon, silicon, phosphorus, and sulfur must be accurately known and adjusted.

The great tonnage of steel continues to be made in the open hearth furnaces and in Bessemer converters; but the electric furnace offers advantages enabling it not only to compete, but gain upon the other methods. Year by year the percentage of steel made electrolytically increases. One factor is that, whereas imported magnesite is required for linings in other equipment — and thus magnesite was all-important until the war — the electric furnace can use without difficulty linings made from domestic raw materials. In peace-time this is not so important and the governing consideration becomes the ability, with the control of heat which electricity gives and the entire absence of the interfering products of combustion, to produce steel on a qualitative as well as a quantitative basis. By this is meant that with chemical control as a guide the iron of known quality can be placed in the furnace, which in a sense becomes the laboratory beaker or crucible under control so that certain amounts of heat can be applied for a definite time to remove carbon. New materials may then be added as one would pour reagents into the beaker confident that the final resulting alloy will be a homogeneous mixture of desired composition and consequently of predetermined physical characteristics.

The electric steel furnace would seem, therefore, to possess all the advantages of the crucible used for the highest grade steels such as tool steels as contrasted with the great open-hearth furnaces and Bessemer converters. The crucible and now the electric furnace have made possible the development of a great range of modern metals known as the alloys. One group of alloys is built upon ferrous or iron metallurgy; the others are non-ferrous. The latter, while originally based upon copper, zinc, and tin may now include none of these in their composition. Metals that a short time ago were museum curiosities are now called by their first names by the machine tool foremen and their helpers.

In the 1924–25 Prize Essay Contest of the American Chemical Society, J. C. Hendricks, of Franklin College, Franklin, Indiana, succeeded in winning one of the national prizes, his

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A Modern Oil Refinery.

This and the many other establishments in the oil industry are monuments to chemical progress. (Courtesy, The Cosden Refinery.)

discussion being on "The Contribution of the Alloys to Civilization." A part of Mr. Hendricks' discussion is quoted below.

"The alloys have been of sufficient importance to man in his progress from cave to cloud to furnish the name for one of the great eras of civilization, The Bronze Age. Introduced, no doubt, by accident and developed by the trial and error method, the alloys were, nevertheless, of great use to the ancients and they have written themselves into history in such terms as 'the sounding brass and tinkling cymbals' and 'Damascus steel.' But the scientific investigation of the alloys did not begin until the latter part of the nineteenth century. Metallography was introduced in 1868 as incidental to the microscopic examination of meteorites and by 1890 the British scientists, headed by Ewing, were determining the eutectic points for several alloys. In 1902 The Report on the Mineral Industry commended the British and French on opening up the scientific study of the alloys and urged the United States to join in the research.

"The properties of the metals which have been modified in alloys may be classified as follows: (1) hardness and tensile strength; (2) elasticity and toughness; (3) malleability and forgeability; (4) fusibility and resistance to heat; (5) coefficient of expansion; (6) specific gravity; (7) resistance to corrosion; (8) electrical resistance; and (9) color and beauty.

"The change in hardness and tensile strength from iron to carbon steel and then to the steel alloys brought to a close The Iron Age. The introduction of manganese, chromium and tungsten into steel made modern machinery possible. Manganese has been the 'leavening agent' of steel and has given low-carbon steel strength and forgeability. Nickel, vanadium and molybdenum have given steel the necessary wide elastic limit and great toughness to withstand the terrific vibration of light automotive machinery. Osmiridium (osmium and iridium) and monel metal (copper and nickel) have given the required hardness for pen points and chemical and surgical instruments where non-corrosion is also a necessary property. Babbitt

(copper, antimony and tin) and bronze (copper, tin and often zinc) furnish soft metals of low coefficient of friction for use in bearings.

"A low melting point was demanded for such uses as safety plugs, automatic sprinkling devices and the joining of such metals as lead and tin. Electrical fuse wire also became necessary. Rose metal (containing bismuth and tin) and Woods' metal (bismuth, tin and cadmium) supplied the need. High speed tools were impossible until a tungsten steel was developed which would hold its temper under the provocation of great heat.

"Some of the most gratifying work has been done in correcting the coefficient of expansion of metals for particular uses. Three special degrees of expansion have become important: (1) the zero coefficient; (2) the coefficient of glass (about .000009); and (3) the coefficient of the enamel of the teeth. The zero coefficient, necessary in pendulums, tapes and other standard linear measures, was first obtained with platinum-iridium but invar (iron and nickel) is cheaper and just as good. For a long time platinum was the only metal which could be fused in glass on account of differences in expansion. For several years after its invention our scanty and costly supply of platinum threatened to hold up the development of the incandescent electric lamp, but platinite (nickel and iron) solved the problem. Copper, silver and cadmium amalgams are used in dentistry.

"The aëroplane and automobile industries have sought a very light, strong metal. Magnalium (magnesium and aluminum) is very strong and only one-fourth the weight of steel. Duralumin (copper and aluminum) furnishes a beautiful, light metal for utensils. The present great industrial use of chemicals makes the use of non-corrosive metals imperative. Monel metal, high nickel steel, stellite (cobalt, chromium, iron and tungsten) and platinum-indium are such metals. Many electrical devices and appliances require high or constant resistance. The use of rhotanium (rhodium, palladium and gold) in the

pyrometer made the first high temperature measurements possible. German silver (copper, nickel and zinc) and manganin (manganese and nickel) furnish high resistances, and nichrome (chromium and nickel) is used in heating appliances.

"Many alloys have won favor for ornamental use because of their color and luster. Brass (copper and zinc) and bronze are extensively used as metal trimming, gun metal (bronze low in tin) is used in jewelry and watchcases, aluminum bronze (copper and aluminum) furnishes an inexpensive gilt for radiators, sterling silver (7.5% copper) makes a very good grade of table silver, and white gold (about four-fifths silver) is a substitute for platinum in jewelry.

"Over a hundred alloys are now in use and they are indispensable to modern civilization. Someone has suggested that this modern age growing out of the Age of Iron be called The Age of Steel, but it would be more fitting to designate it The Age of Alloys."

The wide adoption of a metal frequently waits until science shows the way to large production. Within the memory of man now living, aluminum, originally called aluminium and still so designated in Europe, has come off the museum shelves, where it was placed at something like $50.00 a pound, to take a ranking place among the utilitarian metals and is now produced by the millions of pounds. It has been through research that new uses for aluminum have been developed, and where a market was found with some special requirement it has been the chemist and metallurgist who have found means of so changing the properties of the metal by alloying it with other substances that it would meet the particular demand. This aluminum, because of its lightness, is desirable for aircraft; but alone it does not have requisite strength. Alloyed with magnesium and a trace of copper it acquires necessary strength without material sacrifice in lightness. It is interesting to note that occasionally while research forges ahead of nature in an effort to find a job for some metallic element, developments from quite another quarter produce a demand for just such a

material. Tantalum, discarded as an incandescent lamp filament in favor of the higher melting point tungsten, is now employed in the radio industry. Selenium, for years recovered as a by-product in the refining of copper not for its value but for the sake of copper purity, is now used in glass manufacture and may become of value to replace sulfur for special purposes.

The comparatively rare metals have their own special fields of usefulness. At one time counterfeit coins were made in Russia by gold plating platinum. Most of the platinum comes from the Ural mountains and this counterfeiting was done before the unique properties of platinum were appreciated. It was then a base metal as compared with gold; it is now much more valuable. Platinum is indispensable in scientific work. In a chemical laboratory it is used in the form of crucibles, dishes, foil, wire and other forms because it is not attacked by most reagents, and reactions carried on in platinum vessels suffer no change due to the solubility of the container. Many fusions and ignitions are carried on in platinum vessels, while in analytical work platinum gauze may be used to plate out a metal from solution or used in countless ways. In the chemical industry platinum is the catalyst in the contact process for the manufacture of sulfuric acid. This acid is so basic to the chemical industry that statesmen have pointed out the possibility of measuring the civilization of a country by its consumption of sulfuric acid. It is platinum gauze which acts as catalyst in the oxidation of ammonia to nitric acid. Platinum is used for electrical contacts and alloyed with iridium is used for thermocouples and for pyrometers with which high temperatures are accurately measured. Platinum alloyed with the rare metal iridium is largely used for pen points and in dentistry.

These really necessary uses have been made more difficult because fashion has fastened on platinum as a medium for jewelry. It does offer properties attractive to the manufacturing jeweler; but its greatest virtue is its high price, a mark of quality to the indiscriminate though well-to-do buyer, and since

profits are usually on a percentage basis, this fad in jewelry has been encouraged by the trade. The leaden color and the softness of the metal would seem to be disadvantages for the art of decoration; but these are lost in the determination to have platinum continue popular. Indeed even the war emergency had little effect upon this situation.

In the chapter on communication mention was made of a new alloy designed after careful chemical research to have a greater capacity for carrying messages than those heretofore employed. It furnishes an illustration of how with sufficient scientific data on the behavior of elements and their compounds it is possible to meet exacting specifications.

Metals are often protected by other metals, as well as having their own character changed to give them peculiar qualities. Heat treating and case hardening are examples of the latter. Both depend on the fact that the size and arrangement of crystals in the metal have much to do with its physical condition. In case hardening just the thin skin of the metal is made extremely hard. Intricate parts are sometimes fashioned in soft metal and then hardened by heating and suddenly plunging the material in a bath which automatically controls the temperature to which it cools down and this in turn has a bearing on the crystal structure. Heat treatment is carried on more scientifically with the employment of muffles, pyrometers, and chemical control. Photomicrography has been of great assistance in this work. Sections of metals are ground and polished and the polished surface etched with chemical reagents selective in their action, so that a photograph will reveal the character and distribution of the masses of crystals which determine the properties of the metal. Soft base metals are sometimes protected by plating upon them a skin of a harder metal. This same method is used to protect against acids, gases, and fumes. Asbestos pressed upon sheet metal with a bituminous binder is also used as a protective coating, particularly where acid fumes are to be met. One of the most familiar coatings is that of zinc, which is commonly called galvanized

iron. Thin sheets of iron are cleansed by chemical dips such as a sulfuric bath and then passed through a flux, of which zinc chloride is an important part, and then through the molten zinc which crystallizes out in a thin film, giving the characteristic brilliant zinc crystals on the surface of the metal. Zinc is also used to galvanize wire, rods, and pipe.

Tin plate is based on the same principle and consists in coating iron sheets with thin films of tin. Much research has been devoted to recovering metallic tin from old cans. One successful process disposes of its product in the form of tin tetrachloride for which there is a demand as a weighting material for silk.

As is well known, most metal shapes are made by casting the molten metal in a suitable mould. The finest ones may require months in the preparation of the sand surface which is to impart the design to the finished casting. Moulding becomes a real art in such cases. Other times the moulds may be of plaster or even of gelatin. All of these processes require the mould to be made for one impression only. This gave rise to a demand for a metal such that it could be cast in a metal mould to be used over and over again. To-day vast quantities of small parts are cast in metal dies, the product being known as die castings. Good metals for this purpose must first of all have the requisite strength when completed, must have such a melting point that they can be made to flow from the reservoir of molten metal to the die casting without difficulty, and the composition must be so constant that any allowances made for expansion or contraction in cooling may be depended upon continually to yield first class work. In one sense the linotype and monotype machines produce die castings. Here antimony-tin mixtures are used, the antimony imparting the unique property of expanding slightly upon cooling, rather than contracting as do most metals.

The extrusion of small size pipe and of rods is a labor-saving, cost-reducing method impossible except for metals designed with the help of the chemist to make possible such operations.

Metals of distinct melting point are contrived to serve as safety plugs in boilers, these plugs melting when the heat becomes excessive, thereby forestalling an explosion. Alloys that will melt much below the boiling point of water are sometimes used in sprinkler systems where, with any abnormal rise of temperature, they melt, permitting the water to shower down. There are instances of such sprinkler systems, installed under the cornice of buildings to protect them in case of fire across the street, letting go on a hot day, much to the astonishment of pedestrians below.

These low melting point metals are also used to fill in engravings on dark backgrounds, while solder may be of either low or high melting point. The low melting point variety may contain lead, tin, bismuth, and cadmium, while for the higher melting points pure metals, even silver, may be employed. Occasionally some one has the fortune to find in natural ores the right combination of metals to yield a useful alloy. One of the nickel-cobalt combinations named monel metal is an example. The effort here is not to separate these constituents by a refining process but to remove the gangue without disturbing the proportions of nickel, cobalt, and the trace of iron which yield a metal particularly resistant to many forms of corrosion.

Any one of the big metal companies has a weekly, if not a daily, opportunity to purchase from some inventor the rediscovered lost secret of hardening copper or it may be some other mystery he is prepared to disclose, such as the formula for the Damascus steel or the Toledo blade. Modern metallurgists believe they have independently discovered methods such as the ancients used, that tempered copper was nothing more nor less than a bronze involving tin, and that none of the alloys of old are beyond the realm of possibility if the market is developed.

Ancient bronzes in contact with earth and subject to weather conditions for centuries are found so badly corroded as to give little clue to the original design. Electrochemists have found

by making these oxidized objects the cathode where hydrogen will be evolved they can cause a restoration to take place which brings out even the fine engravings placed there by the artisan thousands of years ago. Circlets of greenish masses of oxide have been reduced to clean metal bands formed of a coiled serpent delicately carved. Coins have been made to show the bust of the Emperor whom they were fashioned to honor, and statuettes, formerly mere masses of oxide, have been restored in all their graceful lines.

It is difficult to imagine our world without the abundance and variety of metals which we enjoy. Many metals can be used over and over again, how often is already the subject of research. Some metals seem to be deposited in limitless quantities; others are severely localized, as, for example, tin and nickel. In all cases conservation is in order and by conservation the chemist always means efficient utilization. This is another way of saying applied chemistry.

Breather Bag Under Construction.

A breather bag is really a balloon, usually some 25 × 45′, consisting of cloth especially treated with a glue-glycerine mixture which makes it impermeable to gasoline vapors. The breather bag is suitably housed and connected with storage tanks. When the tanks become heated in sunshine the vapors in them pass into the bag rather than escape to the atmosphere as formerly. By adopting this plan millions of gallons of gasoline can be saved annually. (Courtesy, Standard Oil Company of Indiana.)

ACADEMY OF

Chapter VIII

MATERIALS OF CONSTRUCTION

So long as man used only such things as he found in nature, his building program remained definitely limited. Sun-dried brick and the adobe are useful only in hot dry countries. Their physical characteristics limit the height and size of structures, as well as the loads they can carry. Some notable structures of old, temples and shrines, have long since been reduced to ruins, and some of the more elaborate which were of decorated wood were long ago reduced to ashes. The structures of massive stone like the pyramids, which have come down through the centuries, and the masonry castles of the Middle Ages, are wonderful examples of what can be done with stone and mortar; but such buildings are of no significance in modern civilization and would be of no value in such industrial centers as those of our present day. It was a Chicago contractor who refused to enthuse over the pyramids, remarking that they looked all right but that there was no market for them. Imagine erecting a building to house the thousands which crowd into a modern office structure without the modern materials of construction.

Ceramic materials, those made from clays and fired, were among the first used by the race. They still play an important part in building, and, utilizing modern science, the clay worker of to-day is able to produce both a superior quality and a much greater variety of sizes, shapes, textures, and colors, of building units. The phenomenon of clay ripening still remains without an adequate explanation; but much is known regarding the control of this process. Some contend that the changes which take place are brought about by bacterial action; others prefer the theories of colloidal chemistry, and certainly the contributions of physical chemistry have enabled the ceramic chemist

to determine with much accuracy the physical and chemical properties of a long list of clays used even yet in empirical mixtures in the ceramic arts. Clay-working machines have been developed; but in many places the craftsmen still believe it to be necessary to mix the clay by treading upon it with bare feet. It is now known why the ancients required straw in the making of brick, and while those old craftsmen learned by experience that the straw provided an essential ingredient, they probably did not know what it was. The ceramic chemist knows that the straw furnished the colloidal material that served as a binder and deflocculated the clay.

Chemists by extensive analysis, firing experiments, and physical tests have shown what impurities in clay cannot be tolerated and have devised ways to remove them. Impetus was given this work during the late war when domestic deposits, as for example in Georgia, were drawn upon to replace raw material previously imported, but for which there was no room in ships engaged upon war missions. It was found that by suitably washing and purifying these deposits qualities could be secured which formerly had been believed obtainable only in imported clays.

Optimum temperatures have been determined for the firing of the various wares and a range of cones provided which melt at definite temperatures and are therefore of great value in controlling kiln operations. By placing a series of cones, representing lower and upper limits of temperature, in the oven, the degree to which the points bend over, collapse entirely, or remain erect indicate what temperatures have been reached in the interior of the furnace. In these days of electrical and optical pyrometers, some of them of the recording type, the greater accuracy and permanent record which they afford make them preferable for much of the fine work.

Studies on plasticity and its cause, upon texture and strength have led to the wide use of moulding and extruding machinery; so in the manufacture of roofing tile, for example, the tedious process of forming the clay over a tree trunk, as was practiced

in California in Spanish days, is a matter of history. Add to this the chemical knowledge of inorganic pigments, of color changes to be expected in new chemical combinations taking place in the fire and those obtained with the aid of colored glazes, and there becomes available a selection of ceramic products well calculated to satisfy the requirements of modern builders. The natural sources of colors in ceramic ware are due to impurities in the raw materials or, as indicated above, to added pigments. Many of the raw materials when pure are white and when burned to the finished ware produce a white mass. China clay, manganese, lime, alumina, and silica would give white products but for the presence of minute quantities of impurities, especially iron. Iron may be present as one or more of the many oxides of the element or of iron in combination with silica and alumina. There may also be carbonate, iron sulfide, and complex mixtures. Some ceramic raw materials like bauxite and magnesite may be yellowish in color due to limonite. An indication of the variables which may influence the color of iron compounds in finished materials may be of interest. Of course, the quantity of the oxide and its nature will have a bearing. The amount of other constituents is important, as is the temperature at which the material is burned and the composition of the gases coming in contact with the ware during burning. The extent to which the piece is vitrified is another variable. The red one sees on terra cotta is often a surface coat produced by spraying a solution of ferric chloride on the dry ware before firing. After firing, the terra cotta has the well known red color. The brown colors begin to replace the red as soon as fused or vitrified material is formed to any extent.

Buff colors, as in buff brick, are composed of different colored materials occurring as tiny areas or dots varying from white or yellow to brown, red, and black. The size and distribution of these different patches of color, as well as their proportion, give us a range of shades.

Black ware is obtained with ferrous and magnetic oxides,

sometimes with unburned carbon added. In addition, when the ware is being rapidly heated to higher temperatures a part of the air is excluded so that the carbon-bearing matter is not burned out before the surface begins to vitrify and thereafter prevents the oxidation of the carbonaceous matter. Black objects are seldom wanted, but may be easily obtained through the improper or unskilled operation of the kiln.

Much of the information used in obtaining colored ware was first derived in ascertaining the causes of the failure to produce colors especially wanted. Artificial colors are now frequently added, as, for example, cobalt oxide where blue is wanted, and chromium nickel for green.

With a knowledge of how to obtain these shades has come a technique enabling pottery workers to obtain in finished ware sufficient graduations of tint to enable very artistic tiles for decoration purposes to be produced. These may even form parts of a mural decoration, or a single tile may simulate a work in oil or water color. Such achievements add greatly to the range of materials available alike to architects and artists.

Closely related is terra cotta prized for the range of its coloring, its fine texture, and the extent to which it may be moulded and formed with a finish which frequently imitates popular building stone. It is widely used for interior as well as exterior trim and may be used entirely for the façade of the largest buildings.

Studies similar to those which underlie the perfection of fine ceramic tiles, pottery, and other objects have been carried on with respect to the heavy clay products such as building brick. This ranges from the common variety to wire cut, hydraulic pressed, vitrified, and enameled brick of great density and variety of color, some being made to special specifications. Hollow tile, another product of modern ceramic chemistry and mechanical engineering, is particularly useful in modern structures where at last a high degree of fire resistance is demanded. Consider the advantages which such a material offers in light-

ness of weight, resistance to the transmission of heat, cold, and sound, ease of erection and alteration, and it is easy to understand the trend toward such structural units in office buildings and apartment houses.

But the true basis of the present day extensive use of brick, tile, terra cotta, and the like is, aside from small dwellings, the great supporting structure of steel and concrete. The most imposing buildings of brick and stone are limited in height by the very weight of their walls, and it becomes uneconomical to increase their thickness sufficient to carry additional stories. One who sees for the first time a modern skyscraper in the course of erection never forgets the impression which the sight of the brick or tile curtain walls begun simultaneously at several levels makes upon him. The true structure is the steel and concrete. The brick and tile merely keep out the weather. There is a distinct architectural difference in buildings marking the introduction of steel and this has since been modified by the employment of the world's most plastic of building mediums — cement — and the concrete made from it.

The earliest use of structural iron appears to go back to India, where the pillar of old Delhi was erected in the year 310 A.D. George Brinton Phillips in the American Anthropologist, Vol. 26, Nos. 2 and 3, recounts in interesting fashion the discussion on "The Antiquity of the Use of Iron" and reports that even steel, though perhaps not recognized as such, is identified with the ancient civilization of India. While the Delhi pillar is the greatest single piece of such structural material identified with antiquity which has come down to us, it appears that the ancient Hindoo ironsmiths forged another pillar twice the length of that of Delhi. This was erected at Dhar in central India about 321 A.D., but this column is now broken into three pieces, one of 24 feet, one of 12, and the third of 6 feet. The fact that the 24 foot section is a square 10 inches on a side, the piece 12 feet long octagonal through part of its length and then circular, and the third piece a square of 10 inches with a bell capital indicates considerable skill on

the part of these early craftsmen who must have had appliances to handle masses of such weight, though traces of these machines and tools appear to have vanished.

At Konarak, according to Phillips, there are other evidences of iron work on a large scale, and near the building of the Black Pagoda were found fragments of iron beams apparently for structural purposes. There are 29 pieces, 5 or 6 feet in length, supposed to have formed the part of 20 complete beams for the temple which was built in the ninth century but not completed until the thirteenth. These beams were made by welding together small masses of wrought iron, and it appears that the two largest may have been 35 feet in length by $7\frac{1}{2}$ inches square and weighing three tons.

The evidence of steel in those early days is to be found in the analysis and microstructure of certain wedges which contain enough carbon properly to class them as steel and they could be hardened by heating and quenching. Some argue that the wedges were more likely the work of the Greeks, who saw service in India, rather than of the Indian smiths.

While much of the early work in the manufacture of structural steel was empirical, real progress was not made until steel makers came to realize that they were engaged in an essentially chemical business. The principal problem which seems to have interested American steel makers has been tonnage production, and the extent to which research has been pursued by the industry is disappointing in view of the volume of business done and when compared with certain other industries, such as the electrical. While many of the mechanical improvements in steel mill machinery and in devices for handling the finished members must be credited to American genius, the advances due to research on underlying scientific principles must be credited elsewhere. It has been stated that Sir Robert Hadfield did not have a laboratory attached to his great steel works; he had instead a steel works attached to a laboratory and as a result has been made famous by his contributions to the metallurgical art.

This is not the place to discuss the chemistry of iron and steel nor to describe the process of steel manufacture, for that is well known. It may be pointed out instead that the important advances are the result of the work of chemists and metallurgists, and that further progress will be due to the systematic application of scientific methods in the solution of the industry's problems. The most important contributions of late years have been the series of alloys frequently mentioned in this book, for they are important in all fields of human activity. New alloys are appearing from time to time, some offering no improvement over their predecessors; but occasionally one is found that satisfactorily fills an important need.

Science has performed a particularly important task in devising methods for testing structural steel members. Not only are samples taken from the various mills, but testing machines of enormous capacity have been devised and of a size admitting columns, girders, "I" beams, and angle iron so that strength tests may be carried out on full size specimens. This work has even extended to tests under temperatures that might be encountered in a conflagration, keeping the column or girder under load just as it would be in case a warehouse burned. Research is in progress at the moment on the fatigue of metals subjected to alternate stresses. A study of the change in structure which comes about under such conditions may lead to methods for determining in advance of failure the percentage of useful life served so that replacements may be made in ample time. The motion picture camera, using a microscope as the lens, has been used to advantage in recording the transitions which take place.

Another method for determining the strains and stresses upon structural members depends upon the use of celluloid models of the member in question. When these models are subjected to stress and strain and viewed with polarized light they show figures which indicate not only the point of greatest stress, but the distribution of the load and many other data of value in guiding the designer.

Modern building materials, while using their greatest tonnage of iron and steel, include in their list practically all metals, even gold, which may be used in plating or metal work. Copper, bronze, galvanized iron, tin, and lead are found universally and, as we know them to-day, involve much chemistry between mining, manufacture, and final use in service. Enameled metals are also a part of modern buildings. These enamels are of porcelain or glass-like, and some, as for example the lining of tanks used in the beverage and dairying industries, are actual glass. Metals are enameled both for their protection and for the appearance the smooth white surface gives them. The manufacture of the enamel calls for raw materials as far away as Greenland, and the preparation of the enamel is an art in itself. The process of putting an enamel upon an iron surface is complex and a deal of research has been devoted to the study of such defects as "fish scaling," cracking, and other flaws which expose the underlying metal to corrosion, causing chipping of the enamel and discoloration. It has been found that the occlusion of gases in the metal may have an important bearing, while some iron and steel works produce a grade of metal prepared particularly to be enameled. Enameling involves the use of colors and glazes, and really belongs among the ceramic arts.

Buildings employing steel are now-a-days almost always of steel and concrete construction. The steel structure can withstand torsional stresses better than concrete; but concrete will support great loads applied vertically, so that in combination we have an almost ideal structural material. Where modern steel and concrete structures fail, one is justified in looking for errors in construction or for overloading. The reinforcement not only enables the building to carry greater loads with safety, but acts as a protection to the steel, preventing corrosion and rendering collapse on the occasion of a fire less likely.

Many things are now possible in building which could not be undertaken prior to the development of concrete construction,

and when more is understood of the scientific principles underlying the hardening of cement, the relation of size and kind of aggregate and quantity of water used to ultimate strength, still better work may be expected. When we can add to this information the data which the future research in metals may be expected to yield, buildings should be well nigh permanent. We find a tensile strength of fifty thousand pounds in iron; but one investigator has calculated that the absolute cohesion of metals might be expected to result in a tensile strength of five million pounds per square inch.

Cement finds use as a binder for other materials and aggregates which characterize concrete. When used with asbestos and coloring materials, a variety of pleasing roofing tiles or shingles may result. When used with bits of selected granite or marble and polished down, an imitation of rare building stone may be produced, and duplicates of some of the famous porous and disintegrated stone have been successfully made with cement. Cement is also used as a mortar, having largely replaced lime mortars for many types of buildings. We find artificial abrasives mixed with it when it is to be used in floors where the duty is heavy and in stair treads of public buildings. Where a thin coating will suffice, as in lining a tunnel or in protecting the steel of railway structures, the cement gun may be used. This is a device in which the cement, sand, and water are mixed and then thrown with great force by compressed air against the object to be covered and a very compact coating results which has been used to advantage in building and remodeling. An example of the latter is the resurfacing of a frame house, which can be converted into stucco by a simple process of nailing on the prescribed wire netting and covering the surface with cement from the cement gun. The same method is used for repairing reservoirs, lining irrigation ditches, and constructing temporary partitions.

Another type of cement found in building is that made from magnesium oxide and magnesium chloride known as Sorel cement. The magnesium oxychloride formed when the ingredi-

ents are mixed in exact proportions remains plastic long enough to be troweled into place. It has sufficient strength to recommend it highly for many types of floors.

Gypsum is a compound of interest to chemists. It finds wide application in plaster, in the manufacture of tiles, in slabs for roofing, either precast or cast in place, and in a variety of plaster boards. It is the perfection of gypsum and special lime plasters which makes it rare to-day to see mortar prepared in the old fashioned way where lime was slaked on the job, the hair mixed in, and the mass allowed to stand sometimes for a year before it was considered in proper condition for use.

If ceramic products are our oldest building material, wood is perhaps the most universal, especially in the United States. We have all heard it related how but a few years ago only the clear lumber, that is, lumber free from knots and other imperfections, would be used; but for some years builders have had to use about what they could get, and while the constant demand for conservation and reforestation is beginning to bear a little fruit, America will find it necessary to be cautious and careful or willing to go without ample supplies of commercial timber. Considerable savings have even been made by changing the design of saws so that the cut would not be so wide and the proportion of the tree reduced to sawdust lessened. The Forest Products Laboratory of the Department of Agriculture has shown by physical tests what varieties are best suited for special purposes and the sizes that can be safely used. This has effected a real saving as against the time when, in order to be safe, an oversized timber was put in, thus giving an excessive margin of security corresponding to the excessive size of the timber.

The attention directed to wastes in lumbering has had some bearing upon the trend toward products of wood for materials of building construction as contrasted with the timber itself. These wood products include building paper and roofing paper, both treated with asphalt, tar, and other materials to render them

impervious to weather, of greater weight and durability. Especially impregnated roofing may be finished with slate screenings and may not only be of exceptionally heavy type felt paper to begin with, but thoroughly saturated with one of the many sorts of roofing compounds.

Wall boards and plaster boards under a variety of trade names have been produced by processes very similar to those used in paper making. Some are little more than heavily sized paper pulp, while others employ some such hardening material as gypsum or cement and vary from those which are intended as a surface upon which to plaster the interior finish of a room to board which is advertized as suitable for exposure to weather.

The chemist has been called upon to help provide a number of insulating materials for building construction. The use of partition and flooring tiles has already been mentioned; but here we may direct attention to heavy boards made from bagasse and others constructed from the flax straw where the flax has been raised not for fiber but for seed. These types of boards contain many air spaces and have been particularly useful in insulating against changes of temperature and noise. Heat insulation for boilers and pipes is usually made from magnesium salts or asbestos. Great savings are effected annually by the proper application of these materials and extensive research shows how great are the losses per square foot of unprotected heating surfaces.

A building material typical of our time is glass. We must go back in history a long time to find when glass was not available in some form for windows; but it has remained for the present generation to produce glass in such thickness and with such strength that it may be used for flooring, for step treads, and in fact very much as other ceramic materials. What has been accomplished in the production of window glass would have been impossible without the coöperation of several professions. The mechanical engineer could have accomplished nothing without the physicist and chemist who were able to provide glass batches that could be worked on the new machines, and these

new glasses might not have been devised but for the dream of these mechanical geniuses.

Thirty years ago most of the window glass was made by blowing a cylinder on a hand manipulated pipe, swinging the heavy mass by hand in a pit while the pipe was turned and the blowing continued until the right size and shape were attained. It was notoriously heavy work, and only the most skillful could produce a cylinder with reasonably uniform walls so that when it was split and annealed the entire sheet of glass would be of the same thickness. To-day the glass is no longer melted in small pots. It is prepared in a tank furnace that holds several thousand pounds and which operates continuously, the raw material being shoveled in at one end and the finished molten glass dipped from the other. This glass is transferred into a large pot in one process and from this pot a machine with an automatic air blast draws the cylinder forty feet in length at a speed which, with the viscosity of the glass and the pressure of the air, results in walls of uniform thickness and free from imperfections. This cylinder is then cut into definite lengths, flattened, and annealed at a rate which enables one plant operating the process to produce 135 tons of window glass per day.

But even this does not satisfy the manufacturer. Other methods have been devised so that the cutting and flattening of the sheet may be avoided. An iron bar is introduced into the tank and, with the glass gathered on this, it is slowly pulled so that the glass may harden enough to cause a sheet to form. Slowly by machinery this sheet is then pulled over a roller and through annealing furnaces or a lehr to come out flat and ready for cutting to size at the other end. Another plan is a variation of this one in which the sheet is pulled vertically and is both cooled and annealed as it passes upward, thereby avoiding the difficulty of the roller which changes the direction of the sheet in the other process.

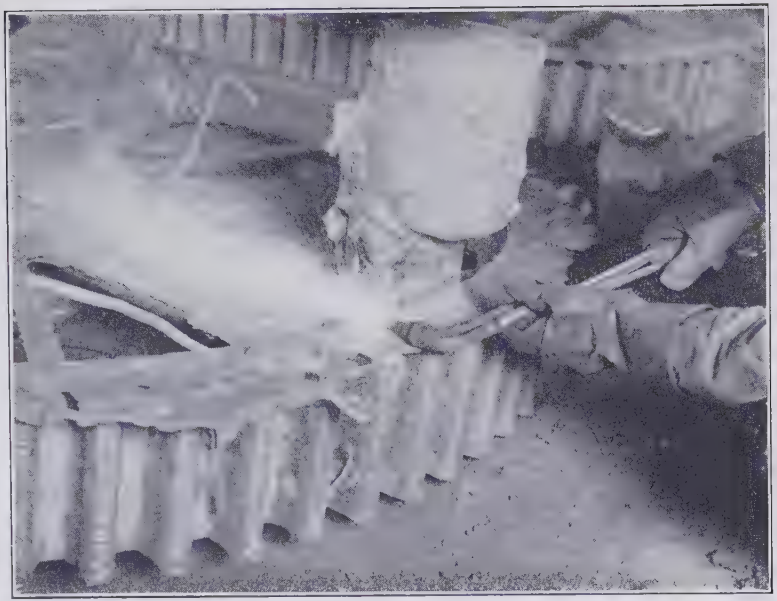
The tendency of window glass to shatter when broken led to the development of wired glass for use in windows facing adjoining property, so that in case of fire the glass might not

GIANT CARBON ELECTRODE PRODUCED BY ELECTRO CHEMICAL METHODS.

Modern industrial electrodes are made from the size of a pencil to those weighing more than 1400 pounds per 5 foot length. The larger electrodes, some of which are molded, some extruded, and others built up, are capped and threaded to enable sections to be so joined as to feed the furnaces with a practically continuous carbon electrode. (Courtesy, National Carbon Co., Inc.)

Oxy Acetylene Welding.

This manganese steel and sand sucker required a 3-inch band of manganese steel $\frac{1}{4}$ inch in thickness to be added to its inner edge. This was most economically accomplished by the use of oxy-acetylene welding blow pipes. (Courtesy, Linde Air Products Co.)



Cutting Risers in Steel Foundry with Oxy-Acetylene Cutting Blowpipe.

Oxy-acetylene welding has become indispensable in foundries. The cutting of a riser from a large steel casting is shown in the illustration. It is by all means the most economical way of doing such work. Oxy-acetylene and oxy-hydrogen are also used to cut out gears and other mechanical devices from great billets of steel which could not be satisfactorily cut in any other way. The use of such industrial gases also makes possible the salvage of many imperfect castings. (Courtesy, Linde Air Products Co.)

break and give rise to drafts or allow the entrance of sparks and flame. In this glass finely woven wire is embedded in the mass, which is left opaque for most purposes, but ground and polished on both sides where clear glass is wanted. In some cases this wire glass is objectionable on account of appearance; so another form of non-shatterable glass has been devised. In general, this consists in placing a sheet of celluloid between two sheets of plate glass and by means of temperature, pressure, and other devices, bring the three pieces into absolute and continuous contact. This glass will withstand a surprising amount of shock, and if broken, the pieces remain in place. By combining a number of pieces of glass with sheets of celluloid and by using glass of different thicknesses, composite plates may be built up which will withstand machine gun bullets. Such glass is useful in banks, where it affords protection to the staff, and the thinner sorts find application in automobile windshields and elsewhere where broken and flying glass may be a great menace.

Glass in the form of mirrors is widely used in construction principally for ornamental purposes, and, as has been explained elsewhere in the volume, the production of the mirror is a chemical process.

Rubber is finding its place in building and has come to assist in the fight against the increasing noise of the modern city. Now and then an effort appears to be made to lessen the continual noise of a busy center or to protect workers against it, for it undoubtedly has an affect upon the nervous system. Rubber tiles made for the most part from recovered rubber and rubber substitutes are now offered in a pleasing variety of designs and colors. Even rubber paving is under test in London and in Boston. We may expect a greater use in future of this material which in many places shows admirable wearing qualities besides having an elasticity demanded by some services and the overcoming of sound which is so desirable.

Modern building with the materials which science has placed at its disposal and the skill which has been developed by those who design and erect these structures appears now to be limited

more by other factors than by materials of construction. We find new regulations in New York, for example, requiring certain vertical zoning to insure light and air for the streets and lower stories. The percentage of the building which must be set aside for stairways, fire escapes, and elevators also tends to regulate the height of buildings. The increased difficulties of fighting fire has led some cities to limit the height of buildings, while the very concentration of workers which enormous buildings bring into a limited area so complicates the traffic and transportation problem as to constitute a limiting factor. So far as can be seen now, therefore, chemistry and the other modern sciences have met the current demand for building materials. What is needed now is further research on the nature of these materials, that greater strength may be obtained and that disasters may be avoided. The use of the X-ray for detecting flaws in metals represents one promising line of research. Improvements in building design to enable great structures to withstand wind pressures and safely bear the burdens put upon their floors have been constantly made, and much has been learned about the proper structure of buildings which will withstand earthquakes. The change in demand, one might also say in style, frequently causes a building to be replaced long before it has served its useful life, so that for the present, at least, building demands seem to have been fairly well met save for those two great factors, rust and decay.

Chapter IX

PERMANENCY OF POSSESSIONS

On every hand there is evidence of the eternal conflict between the agencies of construction and those of destruction. The more complex organisms feed upon the lower forms of life, while everywhere there is a rapidly multiplying host invisible yet busy in tearing down and causing the disintegration of these same complex bodies into their chemical constituents. We take every advantage of the natural forces we know how to use, sometimes for construction and often for taking apart natural formations or the structures of human hands; but we are constantly menaced by these microscopical forms which work incessantly to use our possessions for themselves. We are also often at the mercy of chemical elements which we recognize but which we cannot control and suffer because of chemical reactions which, once started, rapidly acquire a magnitude which makes them unmanageable.

Rust and decay have been recognized as two of man's enemies since time immemorial. So long as replacements could be made with ease, rust and decay were bothersome and simply typified the transient character of this world's goods. These agencies have not lost this significance but economically have become of increasingly greater importance and to-day command all the facilities of science in the effort to counteract and overcome them. Rust, or the corrosion of metals, as the chemist and metallurgist call it, alone accounts for an annual loss estimated at $300,000,000 in the United States. This represents the cost of replacing metal which has rusted to the point of failure or to the obvious danger point and takes no consideration of further losses due to the actual failure of the metal. Thus in petroleum wells corrosion is a constant menace not be-

cause of the mere value of the iron pipe with which the drilled hole is lined but because the entire well may be lost due to the failure of this lining. Wells can seldom be relined, and even if a new hole were drilled, an expenditure of many thousand dollars would be contemplated. One serious feature, however, is the loss of the petroleum which may rise in the well to the point of fracture of the lining and then leak away into the permeable geological formations overlying the solid cap responsible for the well itself. It is obvious, therefore, that the failure of metal in this instance might account for a loss a thousand times the value of the pipe.

Another example might be taken from experience with bridges. Spans have been known to fail because of weakness as metal has rusted away and the interruption of traffic has represented a loss quite beyond the value of the bridge. Such losses may also be caused by what has come to be known as the fatigue of metals. Those who determine the crystalline structure of metals and who express the physical characteristics which make these metals valuable in construction in terms of crystalline structure tell us that as structural members are subjected to alternate strain and stress these crystals become altered, the size of the crystals may be changed, or their relative positions may be altered. Eventually a microscopical fracture appears, and as the metal continues at work this fracture may grow or further alteration of crystal structure may occur until the metal actually becomes fatigued, loses its strength, and the member snaps. Moore, at the University of Illinois, working with funds provided by some of the great metal using concerns, has examined many alloys and metals, using a machine designed to subject specimens to literally millions of alternate stresses. The results have been studied by the tedious methods of the metallographer who grinds and polishes his test specimen until it is as smooth and shiny as a mirror, free from abrasion and polishing scratches, and then etches the surface with reagents designed to bring out certain characteristics. Further, these test specimens have been studied with the aid of the motion picture camera.

Knowing the life history of the test pieces and preparing a complete photographic record together with other data yields information which may be hoped to lead to the application of tests to metal in situ. This might enable us, for example, to tell by comparing the photograph and one of a series taken with a motion picture camera from the beginning of a test to the breaking of a specimen what portion of the metal's useful life had already been given in service. When this is possible, bridge members may be replaced in time to avoid danger and inconvenience. The steel cables on elevators may have a longer life, for they are now arbitrarily replaced to be sure of the safe side, and where metal fails it will be easier to decide whether the failure was the result of sudden strain, improper design or of the fatigue of the metal.

Rusting is a chemical phenomenon. Metals have a great affinity for oxygen and most of them, if not all, will unite with oxygen under the proper conditions of temperature. Oxidation is really the burning of the metal just as the burning of wood is the rapid oxidation of the non-volatile components of the wood. If a wire sufficiently fine be made from iron, for example, it will burn without difficulty in an atmosphere of oxygen. Fortunately for us the air is diluted with four times its volume of nitrogen which acts as a diluent. But for this the world would have been burned to a cinder the first time lightning struck it. Then, too, our iron occurs in masses and, finally, at normal temperatures. As a result, iron does not burn in the accepted sense of the word. It merely rusts, that is, takes on oxygen very slowly and more rapidly where moisture is present.

Some years ago, the water of a great city was not aërated as it is to-day. Its oxygen content was lower and as result the pipe through which it flowed was attacked very slowly. With the aëration of the water came more rapid rusting until by and by a certain hotel decided that it would be well to replace the plumbing. No comment need be made on the cost of plumbing, for it is so well known as to be the butt of many a joke. Imagine the consternation of the owners when they remembered that

their building had been constructed before the days when open plumbing was in style and that to replace the plumbing was equivalent to replacing the building. Construction people usually think of the chemist, if they think of him at all, when it is too late; but in this case some one bethought himself of the chemist and one was consulted. He reasoned that if the oxygen in the water could be satisfied with iron before it entered the pipes rusting might cease. After adequate experimentation, a tank was devised with replaceable plates put there to be rusted with the result that the plumbing is still serving its original purpose protected by this exterior device with which the water can be controlled in large measure. Since this experience, a number of devices have been offered which combine mechanical and chemical methods to treat water to be used in such systems, and where closed systems such as a hot water or stream heating plant is concerned this type of corrosion can be largely overcome.

There is a noticeable difference in the extent and rapidity of rusting. Some iron posts, for example, were used in 1879 in constructing monuments to mark the international boundary between the United States and Canada. Some of these cast iron posts are still in an excellent state of preservation. A considerable difference has been noted by farmers and ranchmen in the life of the woven wire fencing which they have built, and the same differences have been noted with iron plates and bars used in roofs subject to the corrosive action of the air and rain, particularly in industrial centers where the sulfur in bituminous coal descends with the rain in the form of sulfurous and sulfuric acid. Sulfur is burned to its oxides in the furnaces, is thrown into the air with the smoke, and is there condensed with the results indicated. An examination of these various types of iron have led to two explanations, each with its array of adherents. There are those who contend that the purer the iron the more resistant it will be to corrosion, and one great company has built up its business because of the high purity of its product. The other faction insists that it is the presence of other elements

with the iron that bestows the desired quality and mentions traces of copper as one of the most important ingredients. It is known that in apparatus designed for chemical factories iron bearing a large percentage of silicon is far more resistant to acid than other types of this metal. Here again we have an example of the importance of traces in compounds and mixtures.

Where larger quantities of elements are alloyed with iron, non-corrosive metals of growing importance result. Stainless steel or rustless steel, as it is sometimes called, has come into fairly wide commercial use, particularly for cutlery and in many types of instruments. A recently designed tennis racket offers a cast aluminum frame to avoid the twisting wood frame of the past and this is strung with a rustless steel wire to replace the familiar cat gut which so quickly becomes unsatisfactory with changing weather conditions. Chromium is the element largely responsible for this desirable feature, and its employment in stainless steel has led to renewed interest in chromium as a metal for plating. It gives a dense hard surface of high luster wearing some twenty times as long as corresponding nickel plating.

Another type of rustless steel was introduced some years ago under the name of stellite. In this cobalt and tungsten were used to alloy with the iron. This alloy remains the most efficient of the highspeed tool steels.

There are still other types of non-rusting metals, of which monel, named for its discoverer, is the most widely known. Monel metal is a natural alloy of nickel, copper, and cobalt which finds use in a wide range of industries and even in cooking utensils. Many of the pieces of equipment used by food-canning and packing industries are now made of this metal, for the equipment not only has greater life, but, since it is not attacked by the organic acids of the foods, the foods are in no wise affected. Pasteurizers for milk and cream, and the various items of equipment in the manufacture of ice cream are frequently of monel metal which, as may be expected, also finds application in pharmacy and the ramifying branches of the chemical industry.

A more recent alloy is alcumite, one in which, as the name indicates, aluminum and copper are depended upon to give the desired resistance. Indeed, few weeks pass without some new non-corrosive alloy being offered the engineers and the public. There are all sorts of bronzes, steels, and combinations of rare metals, each put forward by its inventor to offer the solution to the corrosion problem. Unfortunately, many experimenters have failed to take into consideration the life history of their samples. Laboratory men have begun with three or four constituent elements, laboriously put together varying amounts of these materials, and tested the resulting alloy without taking the precaution to be certain of the purity of their materials or to know to what extent the character and properties may have been affected by previous casting, rolling, hammering, or other working, or by physical and chemical changes which specialists now recognize as factors of real importance.

A vast amount of this type of work has been done, and in their effort to provide a satisfactory structural material, engineers have exposed metal panels to all sorts of weather conditions, have immersed them in corrosive solutions, and have otherwise sought to apply accelerated tests so that within a short time they might know something of the service to be expected in actual wear. No doubt these engineering tests have been of great value and their importance is not to be minimized. It is evident, however, that this method of procedure will never solve the problem, for it does not touch the underlying fundamental causes of corrosion and rusting. From the scientist's point of view it is not enough to know that a certain combination of metals under given conditions is more resistant than another combination of metals under the same conditions. He cannot consider his work finished until he knows *why*. His experience in other lines convinces him that when he knows *why* he will have taken the greatest step toward determining *how* to prevent these corrosive losses. The last few years have seen a considerable number of well trained research men undertake the solution of this difficult problem. Some theories have been for-

mulated only to be discarded and replaced by more modern ones; but progress is being made. It has been noted, for example, that a certain type of film has been formed on some of the less corrosive metals. So long as this film is not ruptured, the resistance is fairly satisfactory. If the film is ruptured, corrosion progresses at that point. Is there some way whereby a metal can be protected with a self-healing film just as man is protected when healthy by a self-healing skin? If so, then some think the corrosion problem will have been solved.

Elsewhere in this book mention is made of the protection afforded metals by the plating method and as has been pointed out the difficulty here is not so much to find a more resistant metal or alloy with which to plate but actually to secure a film sufficiently continuous really to protect. Just as the greatest dike may eventually be destroyed by the smallest leak, so often is a vessel destroyed because of a pinhole in the plating, enameling, or other protection. One of the common evidences of this is in the spoilage of canned fruits. Here the tin plated on the sheet steel can may have a pinhole and at this point the organic acids of the fruit attack the steel and the can begins to leak upon the shelves. Enameled culinary ware sometimes goes the same road. Galvinizing is an effort to protect iron, which rusts easily, with zinc, which is far more resistant. Sometimes builders' hardware is of iron, copper or brass plated and then colored to imitate brass or bronze; but it soon rusts, for the plate is thin and the wear is hard.

We are using our timber resources in America four times as fast as the forest is growing. Notwithstanding timber resources in Alaska and in other parts of the continent, we face a need for stringent conservation, the seriousness of which has not yet impressed the majority of American people. In some quarters reforestation is under way and much has been done to conserve wood by devising suitable specifications, by redesigning shipping cases and the like, by the substitution of paper cartons where possible, and by improvements in lumbering operations. The rate at which we are throwing away our forests

by covering them with printer's ink and the unrestrained use of all forms of paper is appalling; but the statistics seem to have run into figures transcending the average man's comprehension, for they appear to have made little impression. The Sunday newspaper may still run to one hundred pages, of which no buyer reads probably more than ten per cent.

Before the Forest Products Laboratory was established, architects and millwrights determined what size a beam should be and then made it any convenient number of times larger to be sure it was strong enough. Now the woods are tested and timbers designed, according to the species used, to carry amply the intended load without the waste formerly characterizing this type of building. In some cases, as in railroad ties, we have held too long to a rigid specification laid down when tie timber was plentiful, and small changes are desirable if tie renewals and new ties are to be had at a price the railway can afford. At present the maintenance of tie yards is a very heavy item of railway expense.

Having secured timber of the right size and dimension for a given piece of work, the chemical problem is how so to treat that timber as to preserve it. In some textile mills where a normal humidity must be maintained for the sake of efficient weaving and spinning, timbers may be affected by dry rot. Valuable piles of pulp wood stored for the season's run have been known to suffer great losses because of fungi. Railway ties rot rapidly in some sections of the country and marine structures are constantly menaced by the teredo. In coöperation with the biologists, who study fungi and the like, the chemist undertakes to provide chemicals that will either inhibit the growth of the fungi or tend to control it. The sulfite wood pulp mentioned was saved by spraying with waste sulfite liquor from the wood digesters. It has been found that creosote and zinc chloride will protect the ties. The creosote treatment is preferred in some places and may be merely the impregnation obtained by immersing the ties in tanks or the deeper penetration obtained by a vacuum and pressure method. In this the ties on

cars are run into a cylinder, which is first evacuated to withdraw as much moisture as possible and open the cells of the wood. The pumps are then reversed and the liquid applied with increasing pressure. Zinc chloride does not afford the same permanence of treatment, but does give protection for a time practically equal to the service life of the tie. The spikes wear the holes too large for satisfactory friction before the rains have dissolved out enough of the zinc chloride to invite attack upon the wood.

The extent to which chemistry has aided in protecting marine piling has been discussed in another chapter.

The decrease in supplies of timber suitable for some purposes and the labor involved in erecting various types of wood structures, together with the inflammability of wood and the extent to which it is attacked by insects and fungi, have led to its replacement wherever possible with brick, tile, cement, and metals. Taking advantage of the strength imparted even to members of lightest weight by the introduction of angles, ribs, and other mechanical features, extruded and stamped metal are to be found in many places where wood formerly served. The metal casement and window frame are now common. The reinforced concrete post is replacing the black locust and the cedar post for farm fences. So far no satisfactory substitute has been found for the wood railroad tie; but the inventors have not yet admitted defeat. There is something in the elasticity of the roadbed obtained with a wooden tie not afforded by other forms, and if the latter are used, there is not only a difference in the riding qualities of the train, but the rolling stock itself is affected.

As has been indicated, moisture is one of the elements against which we contend in our effort toward permanence in our structures. Moisture is not only conducive to rusting, but promotes the growth of fungi, moulds, and similar things which feed upon wood and fabric and ultimately render them useless. Wood is also destroyed due to a change in its dimensions which takes place with a difference in extremes of moisture content. Shin-

gles become loosened on roofs through expanding and contracting around the nail and being blown a bit with the wind until a nail is no longer able to hold them in place. Boards may twist and warp. Walls become useless with the change in dimension of their component parts, and so to protect wood it becomes desirable to make it waterproof. This is done by the use of oils or waxes, paints, varnish, and all sorts of things that are intended to fill the pores of the wood and repel moisture. Until recently all the research on this subject had been conducted by men who knew paints and not wood, or by those who knew wood but could claim no extensive experience with protective coatings. The chemists and the foresters have now united their efforts, and it is expected that procedures may be worked out in which there will be taken into consideration the differences in the physiological characteristics of the woods so that proper pigments and vehicles may be selected to give the maximum protection.

Textiles present quite a different problem, for while we want them waterproof, we do not want them air-tight and the greatest objection to the average waterproofed fabric is that it prevents proper ventilation and brings discomfort to the wearer. Obviously the best kind of waterproofing is that which allows the maximum passage of air and which permits moistening the outer surfaces of the cloth, but which prevents the passage of water to the other side. Oil skins, which are entirely covered with some waterproof substance such as an oil, belong in a different class. The more satisfactorily waterproofed fabrics depend in a measure upon the surface tension of the liquid; hence the importance of the outer surface of the cloth becoming moist. Some fabrics, such as wool, have an unusual affinity for water because the fibers are in reality small tubes which take up the water by capillary attraction. There are a number of materials used in waterproofing. Waxes and fats such as paraffin, beeswax, boiled oil, and the like are used frequently in a soap solution from which they are precipitated upon the fabric which has passed through an alumina solution. Waterproofing with alu-

minum acetate is very common, and gelatin and casein are also employed. The gelatin is rendered insoluble by treatment with formaldehyde, tannin, or bichromate, or vegetable marine gums may be employed with acetaldehyde, used to insure insolubility in the cloths. Where canvas is to be waterproofed, similar methods may be employed. Asphaltum is sometimes used as are metallic soaps. A high melting point paraffin is used on duck, and wax mixed with rubber has been used as well. Rubber itself finds employment, being applied either in solution or more recently in the form of rubber latex itself. Rubber from latex may be deposited in cloth by electrolytic methods. Cellulose acetate and pyroxylin are too expensive for application, except in fine goods such as sanitary sheeting and dress shields.

Paper is rendered waterproof by the use of sizings, by being impregnated with paraffin or other wax and to a certain extent by the manipulation of the fibers in the beater. Rosin and casein are among the substances usually employed in sizings.

Another destructive agency is fire, and while for real fireproofing nothing short of non-inflammable substances will answer, there are ways of at least rendering inflammable substances flame resistant. A good coat of whitewash has been found an effective means of affording a slight protection to wood. Wood may also be impregnated with inorganic salts or solutions like sodium silicate, which afford a certain amount of resistance to flame if not to fire. This may be important in retarding the spread of flames and hence of fire.

Extensive experiments have been conducted on the fireproofing of cloth not only because of industrial hazards, but for the reason that a number of personal injuries occur due primarily to clothing becoming inadvertently ignited. Studies have been conducted on the influence of various dyeing and mordanting operations on the inflammability of cotton cloth, some rendering the fabric more combustible, some having no appreciable influence, and a few retarding burning. As early as 1826, Arfird recommended phosphate of ammonia as a fireproofing material

and Fuchs in 1820 tried silicate of soda or water glass. From that time on, a long list of things have been tried until W. H. Perkin discovered that sodium tungstate and various salts of aluminum with acetic and formic acids were very efficient in fireproofing cotton cloth. Perkin eventually perfected a process which would be permanent, allowing for the washing and ironing of the goods, and in England this so-called Non-Flam process has been extensively used, particularly for flannelette. Perkin used a solution of sodium stannate, which was squeezed out and the fabric then dried over hot rolls. The second bath was one of ammonium sulfate likewise followed by a squeezing and drying process, after which the fabric was washed to removed the sodium sulfate formed in the reaction, leaving in the fiber precipitated stannic oxide. Some authorities maintain that textile fibers cannot be made non-inflammable but that some treatment will cause them simply to char when ignited. Usually fabrics are not flameproofed or fireproofed because of the cost of the process and the fact that most people do not come into dangerous situations. In some factories, caps worn by women operatives are flameproofed and in others aprons, and other parts of clothing which may come into contact with flame are likewise treated.

A comparatively modern fire fighting device is the sprinkler system now universally installed and in some places outside, as well as inside, buildings. These devices depend upon certain valves which let go when predetermined temperatures are reached. The earlier sprinkler heads depended upon the melting of one of the very low melting point alloys such as Wood's metal to release the valve. More recently very thin walled capsules of non-soluble glass have been fashioned and these are filled with an organic chemical, the properties of which are definitely known. The pressure which this liquid exerts on the bulb at the predetermined temperature shatters it and enables the sprinkler head to function. Chemistry therefore plays its part even in this seemingly remote field.

In plants where highly inflammable materials are in process,

the idea of the sprinkler system has been adapted to the particular needs. In one works the trigger, so-to-speak, is a cotton thread which releases curtains of carbon tetrachloride in sections far down on either side of the fire so that notwithstanding the high inflammability of the material the fire would be confined to a small portion of the plant.

Elsewhere attention has been directed to the tax upon our food supply by insect life and what was being done with the coöperation of phytopathologists, entomologists, chemists, physicists, and engineers to combat this danger. It is largely a matter of learning the life habits of the enemy, his natural enemies, his tolerance to poisons, whether sprays or dusts are the most effective, and after such a systematic study to plan the attack with reference to the weak point in his armour. Some information of great value has been discovered somewhat by accident. It was a stockman, we believe, who, after dipping sheep in a lime sulfur solution to rid them of ticks, decided to spray trees nearly killed by the San Jose scale with the spent solution. He had nothing to lose but much to gain by the experiment. Being a keen observer, he noted the possibilities and as a result lime sulfur solution has come into great favor as a spray to combat many orchard pests.

An interesting experiment is now in progress, having for its purpose the discovery of a bait which will lure the cotton boll weevil to its doom. Great quantities of different parts of the cotton plant have been subjected to intensive research for the purpose of ascertaining whether there is some fragrant principle which attracts the boll weevil to feed upon the plant. After a great deal of laborious work certain principles have been isolated and identified. These are chemical compounds capable of being prepared in quantity and with these materials extensive tests are being made in cotton fields each season. The results so far obtained indicate that eventually something may be found which will accomplish the purpose, although thus far the conservative investigators have not been willing to commit themselves.

Elsewhere there has also been discussed the relation of dehydration, pasteurization, sterilization, and the preservation of foods to our food supply. There remains a number of perplexing problems in phytopathology in which the chemist can be of little assistance until the plant specialist has become sufficiently acquainted with the disease to call for the remedy needed. Thus far he has been baffled in many cases. In others he has succeeded by developing plants unusually high in their resistance to disease. Root rot resistant tobacco plants afford an example. It was found that fields designated as tobacco sick because they would not grow further crops were really infested with a root rot disease and that plants selected because of their resistance gave rise to new varieties which would grow on such fields. There are still great losses in tobacco and in other crops due to leaf diseases and to root diseases not well understood, while larger proportions of our root crop such as sweet potatoes are sometimes lost between harvest and the dinner table likewise from causes little understood. Just as specialists in metals have so far failed to solve the riddle of the *why* of corrosion, so many of these plant diseases remain something of a mystery, particularly because those qualified to engage upon such a study are too often assigned the apparently more pressing task of saving a particular field and are not left undisturbed to pursue those long time studies which we know from experience in many directions is essential to the successful conclusion of such research.

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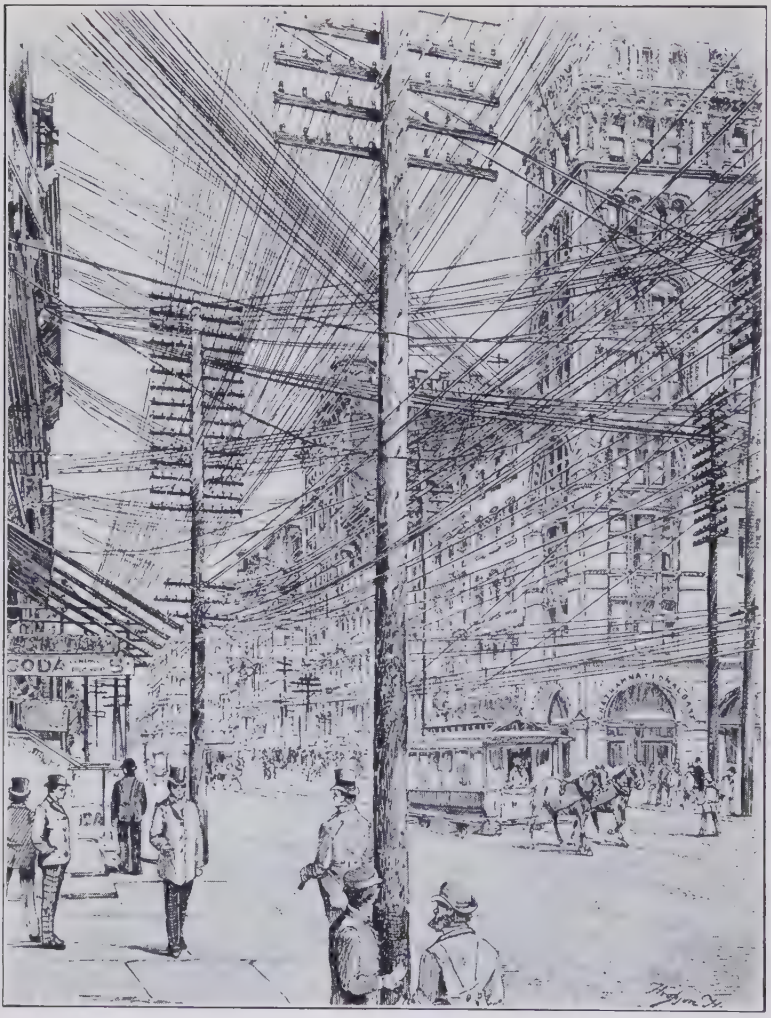


Broadway and John Street, New York City, in 1890.

This picture was made before the days of lead-covered telephone cables, when all wires were carried overhead, strung singly on glass insulators carried on cross-arms on high poles. (Courtesy, American Telephone and Telegraph Co.)

Broadway and John Street, New York City, in 1916.

More than 35 lead-covered cables traverse Broadway near this point. Each cable contains on an average some 700 telephone circuits, making a total of over 47,000 wires under this single thoroughfare. If they were all placed upon a single overhead line, poles two miles high would be required, and if the poles were only as high as the Woolworth Tower, Broadway would be roofed in by 12 such gigantic lines and would be covered with a canopy of copper telephone wires. The lead-covered cable carrying a multitude of telephone wires, each effectively insulated, is made possible through contributions of chemistry. (Courtesy, American Telephone and Telegraph Co.)

Chapter X

HEALTH AND SANITATION

The natural interest which the individual has in the welfare of his body amply explains the appeal which advances in the work of preventing disease makes to all. The close relationship between health and sanitation should encourage any community to adopt the most advanced and vigorous sanitary measures; but unfortunately such is too seldom the case, especially where the sums of money involved are so large as to tempt the politician to take a hand. In such cases the expenditure of large sums becomes the thing and sanitation the excuse. Chemistry points with greatest pride to its contribution to the promotion of health and the prevention of disease or its control. It joins hands with those devoting themselves to the practice of medicine, with the biologists in all their many specialties, and in particular with those cultivating the all important borderlands which lie between chemistry and biology, chemistry and physiology, chemistry and pharmacology, and chemistry and pharmacy. Many of the theories, principles, methods, and apparatus of the physical chemist find extensive application in the study of body processes, phenomena which must be better understood before some of the conquests of disease for which the world patiently waits can be made.

"Chemistry is the fundamental science of the transformation of matter. Physics is the fundamental science of the transformation of energy or power to do work. Life in all of its forms, from its beginning to its end, is the highest, most complex expression of the transformation of matter and of the transformation of energy." A few hundred years ago, chemistry and medicine worked fairly well together, and it is believed that chemistry originated in Egyptian temples where the priests

experimented with simple compounds for the preparation of medicinals. In the sixteenth century, Paracelsus, the great physician and chemist of the time, declared that "the true purpose of chemistry is not to make gold but to prepare medicines," and he himself introduced into medicine some of the materials highly valued at the present day, as for example, arsenic, copper sulfate, iron, laudanum, lead, and sulfur. Shortly after his time, however, chemistry was permitted to drift apart from medicine and the energy of the chemist was devoted more to industrial applications. Fortunately, in our day, the coöperation between the followers of chemistry and the men of medicine is becoming more and more extensive, beginning, perhaps, with chemistry's greatest gift to medicine, Pasteur, "one of the great founders of modern medicine and one of the greatest benefactors of the human race." This coöperation has perhaps been heightened by the realization that the most wonderful of all chemical plants and laboratories is the human body itself where in every cell there proceeds a series of chemical reactions for the most part complex beyond our understanding but upon which the health, growth, and repair of the body depends.

Chemistry, and indeed all science, works in no more difficult field than that pertaining to health and disease. The human organism is characterized by a balance so delicate that we wonder how it is possible to disturb it so greatly, as is done dozens of times daily, and yet have it continue to function. The organisms which invade the body and cause a variety of diseases can be killed with ease in the closed vessels of the laboratory; but the most potent reagents used can seldom be applied without serious detriment to the host when these same organisms are to be combated in the body. The bactericides which can easily be tolerated by the body can usually be tolerated also by the bacteria and those which are most effective in slaying the bacteria cause serious consequences or even death to the individual.

The work is even made more difficult because of the eagerness with which reports of advances are awaited. The mere publica-

tion of the discussions of genuine progress are often seized upon by the lay press, misinterpreted, misunderstood by the public, and confused with the claims of those despicable quacks who prey upon the sick or those who without conscience play upon the ills of the public to exploit them. Those who are fighting the battle for the race against disease are therefore handicapped and may even become discouraged to the point of discontinuing research by the unwarranted criticism of the ultra-conservative.

Medicine is an art which is becoming transformed into a true science, thanks to the coöperative work of all the natural sciences and the establishment of a series of demonstrable experimental facts. At times the chemist may become impatient with the physician who may seem slow to use new remedies he has provided; but the physician's responsibility is a grave one and the too progressive is subjected to as much criticism as the too conservative. A persistent effort is being made to secure better trained teachers for the medical schools and in consequence a better trained profession is being developed. The diagnostician and the specialist are products of the new system, and while the records give ample reason to expect continued improvement in the scientific phases of medicine, there remain some things to be desired in the ethics of the profession.

How fortunate is the closer coöperation between chemistry and medicine may be emphasized by the delays which accompanied the adoption by the physician of some of the earlier contributions of chemistry. Ether was not recognized as an anæsthetic until 1846, though the compound had been discovered more than five hundred years before, and in that interval unnumbered thousands suffered agony because its ability to produce insensitiveness to pain was not known. Two hundred years elapsed after the discovery of magnesium sulfate by the chemist before the physician learned that it would give great relief in the case of burns, strychnine poisoning, and lockjaw. These are but two of many such instances not likely to recur under modern conditions.

When the source of most of the drugs is considered, together

with the factors which influence their potency, it is surprising that so much progress has been made, especially before the time when as great care was exercised in the preparation of remedies as in their prescription and application. Natural drugs come from every corner of the earth and have been collected in many instances by uncivilized or even barbarous people. In nearly all cases, the active ingredients or active principle, as we like to term it, depends upon the character of the soil where the plant was grown, the time of the year when it was gathered, the sort of a season that had been enjoyed, the amount of moisture, the time of the year, the elevation at which it has been grown, and in some cases even the time of day when the plant was harvested. It is easy to see, therefore, that among the first of the services chemistry was able to render medicine was the analysis of the crude materials, the control of methods of extracting the active principles, and the analysis of the resulting material which could then be diluted or concentrated as might be required to give a more standard product. It came to be recognized that not only must the amount of the active principle present be determined, but that there was something important which was not subject to mere chemical analysis. That was the potency of the drug which could only be measured by its physiological action. To-day those who manufacture these compounds for general distribution maintain animal houses where one may find various creatures from mice to horses, given the most painstaking care. By noting the reactions of certain animals of known weight to carefully measured doses the potency of the several compounds becomes accurately known. These physiological analyses are made with the accuracy of a chemical assay. There is one substance which is estimated by determining the minimum dose that will prove fatal to a frog of definite weight. The difference between .00015 and .00016 of a gram in the dose is enough to cause the death of a frog weighing from 15 to 17 grams. Fifteen one hundred-thousandths has no injurious effect; add .0001 of a gram and the dose is fatal. Having proved its value in establishing the value of raw materi-

àls, in securing products of uniform potency and determining this strength accurately by chemical or physiological analysis, chemistry is prepared to render other and even greater services to medicine.

Generally the starting point is the experience of some one who has tried this or that concoction in an effort to cure the sufferings of a fellow. Many times the line of attack is picked up among comparatively savage tribes where some mixture by no means proved the best for the purpose, has been prepared in an impure form and used because of certain beneficial effects, the knowledge having come from experience costing many lives or much suffering. The first step in the scientific attack is to determine the active principle to which the drug or mixture owes its value. The next is to prepare from the natural product a purer drug or medicine uniform in its characteristics. Concentration may be carried as far as possible to minimize the size of the dose as represented by the volume of the material taken, and the ideal is to avoid the uncertainties by synthesizing the active ingredients in the laboratory where control may be absolute. Such synthesis does not obviate the necessity of continued chemical control and of analysis both analytical and physiological. There is too great a risk, too much at stake, to warrant any variation in strict supervision in the manufacture of pharmaceuticals, drugs, and medicinals.

An interesting example of what has been accomplished, following this procedure, has been the search for a cure for leprosy, a scourge of the race since biblical times. For more than sixty years the natural product chaulmoogra oil has been used in India in the treatment of leprosy. The oil had proved its usefulness, notwithstanding its uncertain and variable quality and careless methods of administration. The natural product is irritating and nauseating, and doses sufficient to be potent could not be tolerated by many of the patients, particularly the Caucasians. Real advances were not made until the chemist had isolated the acids which were found to be the active principles and produced an alcohol-soluble salt of these

acids which may be used hypodermically. While the physician, properly cautious and conservative in such matters, is not yet willing to say that positive cures have been effected, he may perhaps be willing to state that some hundred cases are on record in which there is no sign of returning leprosy following a treatment with these new drugs. Synthesis has not followed, as yet, but cannot be considered an impossibility.

With the advent of modern chemistry, the animal as well as the vegetable and the mineral kingdoms are being searched for remedies. In 1855, Addison proved that, whenever the suprarenal glands become atrophied or diseased, man became subject to a peculiar malady now known as Addison's disease and later as Séquard. He showed that animals from which these glands had been removed were sure to die. The suprarenal glands of the adult each weigh about four grams, and until Addison's work it was thought they were of no special importance. Later came the discovery that an extract of the gland caused a marked rise of the blood pressure and in 1901 Takamine succeeded in deleting from the suprarenal glands of oxen the active principle, which he called adrenalin. It required the suprarenal glands of 40,000 oxen to produce a pound of adrenalin, a light yellow crystalline substance dispensed in the form of adrenalin chloride. It is a most potent substance. One two-millionth of a gram will produce distinct physiological results in the body of an adult man and not only is there a remarkable increase in blood pressure, but a constricting effect, and the remarkable increase in blood pressure is due both to the stimulation of the heart and to the constriction of the blood vessels. Because of this adrenalin permits surgery which is practically bloodless, a matter of great importance in certain delicate operations, as, for example, about the eye and the turbinated bones. Adrenalin is now synthesized, an accomplishment to be credited to organic chemistry. Thyroxylin is another example of the use of the active principle of the thyroid gland, which was found to regulate the metabolism of the body. If there is a deficiency, the body may be dwarfed, as may also the mind. If overactive, the

body may grow to abnormal size. Following the isolation of thyroxylin by Kendall, its synthesis may be expected and a long way has been traveled toward this accomplishment.

The notable work of Banting, Best, McLeod, and other collaborators in establishing the value of insulin as a specific in the treatment of diabetes is perhaps best known to the public as an example of glandular extract or hormones in the treatment of disease. No better piece of biochemical research has been conducted than this one, and insulin stands almost alone as the remedy introduced in a perfectly ethical, dignified manner after the most thorough and extended trials that could be contrived. It is notable that those identified with the medicinal preparation of insulin from the pancreas of calves doubted the possibility of its commercial success. They realized that it must be given by injection and believed that the number of units required to be effective would make necessary the injection of such large doses as to be unacceptable to the patient. With the coöperation of pharmaceutical houses, the work of producing a stabilized, concentrated preparation with so large a number of units that the volume of the dose could be reduced was undertaken and the progress has been continuous. The problem of stabilization, and the separation of interfering proteins, presented great difficulties and involved many sorts of chemistry and research of the highest order. Meanwhile, another group has been interested in fixing the chemical composition of insulin in endeavoring to separate it in a pure state, all of which steps are preliminary to its eventual synthesis. Abel has just announced the preparation of crystalline insulin.

The value of glandular extracts is enough to emphasize the importance of the chemistry of the ductless glands, for when this is once understood there may be made available entirely new lines of defense against disease and methods of attack that will bring relief to thousands.

From time to time something is heard of objections to the use of lower animals in establishing the value of medicinals; but the objectors bring with them no constructive plans. As a

matter of fact, the chemist who prepares the material and the physiologist who takes steps to insure its safe use for the purpose intended must be guided by the reaction of these animals and indeed new remedies must be actually tried upon human beings suffering with a particular ailment. This work is done under the most careful supervision by men of wide experience. Few, if any, lives are lost in such tests and the health of thousands upon thousands is protected thereby. It has repeatedly been emphasized that there is no satisfactory way of translating into terms of human reactions the results noted with lower animals, even those similar to man and possessing blood singularly like the human blood. The results obtained through experimental medicine have been of inestimable value not only to the present, but to all future generations.

Such modern procedures have made it possible to develop truly remarkable compounds by means of which such poisonous substances as arsenic and mercury can be introduced in organic salts to combat such dread diseases as syphilis, one of the first diseases to fall under the modern attack. The story of arsphenamine, as the chemist call it, or Salvarsan, or "606," as it is more popularly known, has been discussed in many places. The chemist and the physiologist continue the work in order to overcome objections such as difficulty in eliminating arsenic, possible effect of the compound on other body functions, and greater success in defeating the disease which has remained long intrenched.

These new compounds may accomplish their purpose in one of several ways. The organisms may be killed, as in the case of arsphenamine, or their growth and reproduction may be inhibited, as is the case with Bayer 205, a compound designed to combat the tripanosomes which typify certain of the tropical fevers. This compound, so long protected as a state secret, has since been duplicated in the French laboratories and its molecular structure announced. There was a rumor that German interests hoped to trade the secret of Bayer 205 to the colonizing nations of Europe in return for the lost German

colonies in Africa. It is well known that a treatment that can protect against the tropical fevers is of enormous value, for in the minds of many there is established the belief that the world must eventually look to the tropics for most of its sustenance.

Chemistry has not stopped with the purification and concentration nor the synthesis of natural products. However much may have been accomplished in medicine by the use of natural products, the scope is infinitely widened when there are added those new compounds for which chemistry is responsible and which transcend for specific purposes anything which nature affords. Some of these are clearly the outgrowth of naturally occurring bodies. Thus procaine has resulted from the study of cocaine, which was found to be a very complex molecule, only a small part of which really produced the local anæsthetic effect. The remainder acted more or less as a poison and was responsible for its habit forming tendencies. Cocaine was expensive; it was difficult to sterilize; it was poisonous, and occasionally in minor operations gave rise to fatal results unwarranted by the conditions. After three attacks by leading chemists, one part of the molecule of 43 atoms was found to give the anæsthetic benefits. Another group of atoms introduced a compound closely related to coniine, the deadly principle of hemlock forced upon Socrates, while another group of atoms is related to nicotine. Out of this work has come a number of local anæsthetics, of which procaine is one stripped of all the objections to its predecessor and used in increasing quantities for local anæsthesia.

Acetylsalicylate, popularly known as "aspirin" and used by the ton in America, is another one of these modern compounds used for a variety of ailments and there is a considerable list of anodynes, hypnotics, narcotics, antiseptics, and so on, which have come from the synthetic organic chemical laboratory and have no counterpart in nature. Epilepsy can be relieved, if indeed not prevented, with the use of one of these hypnotics. Luminal and barbital, with its derivatives, have been a great

blessing in the treatment of insomnia and to allay nervous excitement. These drugs are non-habit forming and therefore the greater appreciated.

What has been done makes the chemist bold in hoping, if indeed not predicting, what the future may make possible. The intensive study of the infinitely small things, the electrons and protons, and the progress made in determining at least enough of the constitution of matter to learn how to build molecules, leads to the thought that that very thing will be done more generally in the near future. As has been pointed out, the complexity of the material with which the physician has to work adds infinitely to his task, and so may we not confidently believe that by the time the physician is able to specify the molecule he would choose to combat a disease or right a disorder the chemist will be able to take his plans and specifications and execute them in the laboratory? No doubt some of the diseases which still scourge the race can only be conquered when our knowledge has advanced to the state permitting the achievements such coöperation may make possible.

While some chemists direct their attention to the chemistry of the ductless glands and other glandular secretions, other groups are interested in the significance of such chemicals as a body normally contains. The jocular statement that the man of average weight is composed of 10 gallons of water, 24 pounds of carbon, $\frac{1}{4}$ of an ounce of iron, 7 pounds of lime, less than 2 pounds of phosphorus, $\frac{1}{5}$ of an ounce of sugar, 1.8 ounces of salt, iodine equivalent to $\frac{1}{10}$ of one drop of tincture of iodine, 112 cubic feet of oxygen, 60 cubic feet of nitrogen, and 561 cubic feet of hydrogen is not sufficient. There are still some 10 ounces of other elements with which we must reckon. These include potassium, fluorine, sulfur, and magnesium to mention those occurring in larger amounts. It is only lately that iodine has come into prominence as a necessary constituent of the body, a chemical survey having shown that where goitre is most prevalent the water of the region is

deficient in iodine. At least one city, Rochester, N. Y., adopted the practice of periodically adding potassium iodide to the drinking water supply of the city. Chemists have provided an iodized table salt so the family may have their iodine without knowing about it and various iodine-containing preparations are upon the market. There is still some argument as to whether such inorganic forms of iodine as potassium iodide are the best to use or whether some organic form, for example the iodine from kelp, is the better.

Calcium has also been found indispensable both in the metabolism of man and the domestic animals, and the problem here seems to be how effectively to introduce calcium and have it assimilated. One specialist in hay fever and similar ailments maintains that those having a deficiency of calcium in the blood are the greatest sufferers and adds to his credit cases of relief following the injection of soluble calcium salts into the blood stream.

Another service of chemistry is in the provision of materials for external application. Perhaps the most important of these are the antiseptics such as the Carrel-Dakin solution, which proved of such great value during the war in combating infection in wounds. Fortunately this solution was powerful enough to destroy the bacteria without destroying the body tissue and could be used in the deepest wounds without injury. Iodine in some convenient form either as a tincture or in solid form mixed with potassium iodide serves as a disinfectant for abrasions and wounds. There is a variety of healing, cooling, and sedative materials prepared for skin treatment and rubbing alcohol for external use prepared according to special denatured formulæ approved by the government for medicinal uses.

While there are few medicines prescribed by physicians these days that are not made in great pharmaceutical and drug manufacturing houses, there is also made a large list of so-called proprietary medicines, patent medicines as they are popularly called, and patented medicines as their makers

prefer to have them called. Three-fifths of the annual drug bill of the nation, which in round numbers exceeds $500,000,000, is spent for these proprietary remedies. The number is increasing at a rate quite out of proportion to that justified by systematic research in the chemistry of medicinal products, and whereas thirty years ago about 2700 drug items were on the market, to-day the number approaches 50,000. All of these remedies are not to be condemned and many a physician prescribes proprietary medicines. The provision of simple remedies in a form that can be administered in the home, often far removed from the physician and even the drug store, has undoubtedly saved some lives and certainly much mental suffering. The provision of sugar pills in a variety of sizes, colors, and coatings no doubt saves much mental concern to the man who feeds upon the discussions of ills and who concludes each chapter firm in the belief that that is what ails him, and who but for the simple proprietaries might suffer a worse fate.

The extent to which the public would be exploited by those who stoop so low as to play upon their ills would be even greater but for the watchfulness of the state and federal governments backed by the Pure Food and Drugs Act and by such organizations as the American Medical Association, which frequently publishes the results of its chemical laboratory investigations and does not hesitate to condemn materials which should not be upon the market or which make extravagant claims for their curative properties. The following is quoted from an address by Doctor Paul Nicholas Leech, Director of the American Medical Association Chemical Laboratory in Chicago, on "Chemistry in the Service of Pharmaceutical Medicine," delivered before the American Pharmaceutical Manufacturers Association, January 23, 1925:

"There is opportunity for improvement in the methods of introducing a drug; to illustrate, in how much better taste was the careful and mature announcement of the chemical work on tryparsamide and insulin than the premature, press-

agented story on intarvin. Yet intarvin is of unusual academic chemical interest.

"The advertising departments of the pharmaceutical firms, it seems to me, could well afford to coöperate more closely with the scientific workers before copy is sent broadcast. Many of the difficulties that have been dealt with by the Council on Pharmacy and Chemistry and the Chemical Laboratory can be traced to the copy writer. In a recent case at issue, three letters concerning the composition of a product were answered, and answered misleadingly, by the advertising department without once referring the inquiry to the scientific department. The result was a gross deception innocently perpetrated, yes, but inexcusably perpetrated. It is the duty of the A. M. A. Chemical Laboratory to inform the medical profession concerning the composition of drugs. In line with this, the Laboratory published the findings about the product; the firm, quite chagrined, has seen the error and has ordered that in the future all inquiries and even advertising material of such nature must receive the approval of the scientific department, which should have been done at first.

"Then take the proposition of names — trade names, therapeutically suggestive names, chemical names that hide the active ingredient. It has been shown in case of the leading drugs of to-day that names indicative of composition can be coined and used successfully — mercurochrome, butyn, salvarsan or arsphenamin — and many others, names that are distinctive and with a scientific background; yet there are some firms which jeopardize the introduction of a meritorious substance by endowing it with either a foolish name or a therapeutically suggestive name. Also, one needs but pick up many catalogues and note the therapeutic names for various mixtures, particularly tablets, not at all in keeping with the scientific spirit — Antispasmodic Tablets, Carbuncle Ointment, Sciatica Tablets, Brain Sedative and what not. On the other hand, it is gratifying to note that for many years a few houses have listed their tablet mixtures under the correct scientific name.

"A suggestion, which has emanated from the pharmaceutical organizations but which has not been adopted generally, is the simplification of the number of dosage forms. Why should there be from thirteen to fifteen different dosages for tablets of arsenous oxide? Does it reflect credit for a firm to clutter up its catalogues with practically every remedy possible simply to appear complete? And not quite so bad, but which in the end is just as futile, is the useless duplication of drugs, the outstanding example of which to-day is the host of barbital derivatives. Certainly it is time for the needless products to be discarded.

"In this discussion and particularly the suggestions — suggestions made in the spirit of helpful criticism as seen by the A. M. A. chemists — only chemical questions have been involved. Many believe, I have no doubt, that there is still need of modifying therapeutic claims. This is a matter not within the purview of the Chemical Laboratory, a problem that has been dealt with intelligently by the Council on Pharmacy and Chemistry. It may not be amiss to state, however, that a comparison of present day advertising, particularly in medical journals, with that of two decades ago points out more eloquently than words the coöperation the Council has received from the medical profession and progressive pharmaceutical manufacturers. But even so, the matter of therapeutic claims — claims not properly substantiated — still remains the chief task of the Council and of the pharmaceutical house that desires its propaganda to be looked on with favor."

In the chapter on foods reference is made to the development of a special fat to be used in the case of diabetes. Other materials of a food nature are prepared but, like intarvin, are given on the physician's prescription. "S. M. A." is another example of such products. This is a synthetic food for infants intended exactly to duplicate human milk. It is composed of blended fats, mineral salts, and sugars selected only after careful analysis of human milk, the determination of similar

characteristics in the raw materials employed and a careful selection of these ingredients to give the same physical and chemical constants as the human milk.

The two principal problems in sanitation are water supply and sewage disposal, both involving chemical control and chemical methods of treatment. The fallacies entertained quite generally regarding water have made it difficult to further water treatment as rapidly as new scientific facts are established. To this day it is difficult to convince some folk that water is not always purified by passing through the earth for short distances or that ground water flowing into wells may cause great health hazards. Bacteriology has been of greatest service in establishing some of these facts, and when its results are added to the chemical analysis of the sanitary water engineer, the safety of the water is not only established, but treatment can be prescribed.

Chlorine, a chemical element, is now the most widely used reagent in water sterilization. Unbelievably small concentrations destroy bacteria, and when the plant is under proper control, no unsatisfactory taste is imparted to the water. Copper sulfate is used to destroy vegetable growths whose presence imparts disagreeable tastes, and filtration, with or without previous use of such coagulants as lime and alum, enables water to be given a clear, clean, sparkling appearance. Nearly any water can be rendered safe, clean, and palatable by chemical treatment and subsequent filtration; but this is not always economical, it sometimes being less costly to find a new water supply. While chemical analysis will indicate much, nitrites, for example, being indicative of contact with objectionable organic matter, analysis unsupported by bacteriological evidence is rarely relied upon as the sole ground upon which to condemn water. The principles of water treatment are now well established, and in a given locality the problems are more often those of chemical and mechanical engineering to suit local conditions and for the application of such chemical methods of treatment as the case may require than a matter for original research.

Sewage disposal has a direct relation to water supply, since improperly treated sewage of one town or of one house may contaminate the water supply of its neighbor. Filtration, sedimentation, and the activity of one or another type of bacteria are usually depended upon to render sewage effluent innocuous. Filter beds from which the sediment may be collected for further disposal are often used. The Imhoff tank has many installations, and of late years the importance of activated sludge, a process where the work of the bacteria is furthered by stirring the sludge with air currents, has won its adherents. Occasionally the plan adopted makes necessary a filtration of the treated sewage, and as the engineers of the Milwaukee sewage disposal plant found out, this may involve chemistry. It was only after local chemists showed that the hydrogen ion concentration must be adjusted and the temperature controlled that it was found possible to filter the sludge at all, and but for the application of this knowledge an elaborately designed and expensive plant might have failed of its purpose.

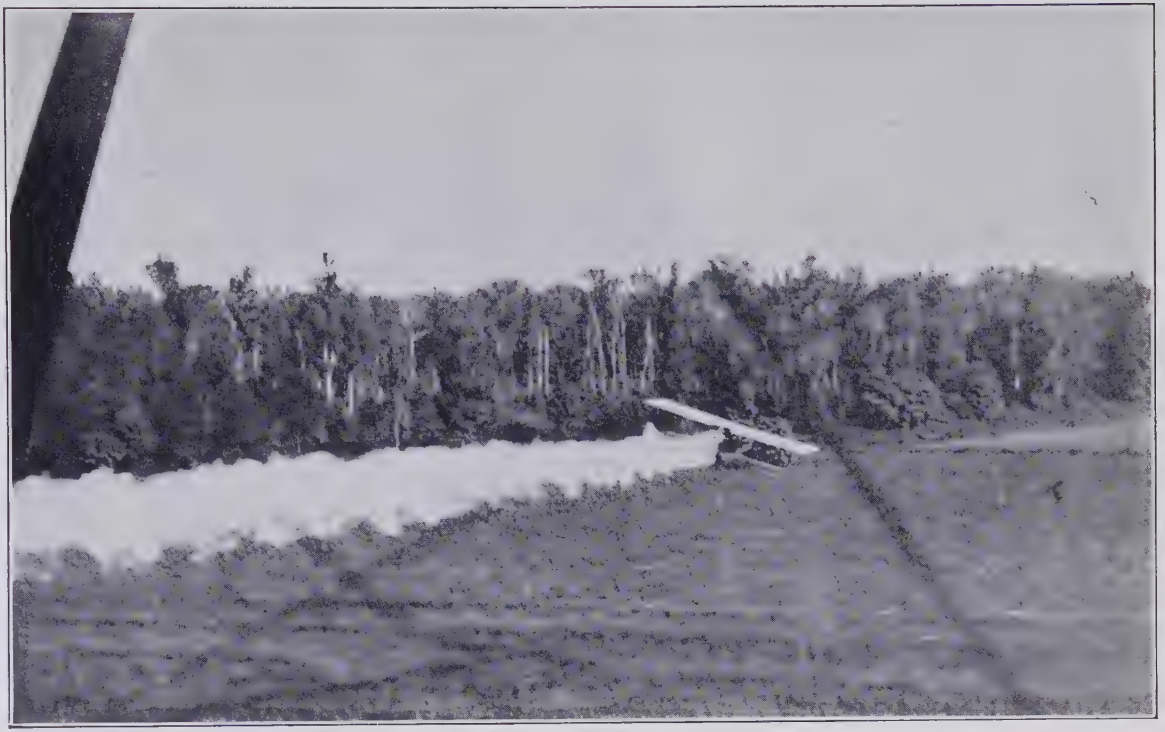
It is not the purpose here to discuss the chemistry of water supply or sewage disposal problems, but merely to remind the reader that these are extensive subjects in themselves and that their success depends upon chemical research and the application of the data so obtained quite as much as does the preparation of potent medicinals.

Most of the research in medicine has until the present involved only biological relations. It is doubtless natural that those who have engaged in such research, having been trained in the various specialties of biology which find their place in medicine, should have only this conception. It has come to be admitted, however, that future progress in this, one of the most important of human activities, will depend in large measure upon the study of the chemical relations which exist and the establishment of the chemistry underlying the body processes. When more is known of how the laboratory which each body cell represents goes about its work, what its raw materials are, what it produces, how these products are distributed, how they

LIBRARY

NONTOXIC SMOKE SCREEN.

The Air Service and the Chemical Warfare Service in combination make possible such a nontoxic smoke screen as the above for the protection of ships and the covering of troops in time of war. Curtains can be dropped by this means, the characteristics depending upon the material used, and the way in which it is laid by the plane. (Courtesy, Chemical Warfare Service.)



COMBATING THE BOLL WEEVIL AND OTHER INSECTS.

The Air Service and the Chemical Warfare Service in peace time combine their talents to combat the boll weevil and many other insects, which threaten crop and forest. This view, recorded through the wing of another plane, shows a dusting plane at an elevation of fifty feet above the plants, delivering calcium arsenate at a fairly rapid rate. The effect of the propeller can be seen in the spirals of dust. It is believed that the airplane will dust more effectively and at lower cost than is possible by any other method. (Courtesy, Chemical Warfare Service.)

are used by other cells of the body, and how that cell disposes of its by products and waste materials then, perhaps, chemistry may make even greater contributions to the conservation of health and the prevention of disease. However, we are not unmindful of the fact that the cooperation of the physician, the chemist, the biologist, and the physicist, during the last fifty years, has made such advances that some fifteen years have been added to the life of the average individual.

Chapter XI

POWER

The interdependence of many factors in forwarding civilization must be just as obvious as the fact that no one thing or small group of things won the war. However, the most superficial consideration will show that a primary difference between yesterday and to-day is the employment of great blocks of energy to do much of the work of the world. Long ago Festus said: "He hath no power that hath not power to use." The World War itself brought a clear realization of the vital importance of the various kinds of fuel as a source of power, and some say that our civilization has in power its real corner stone. Whether it will be the ability of the world to supply sufficient food to feed the population, this depending in one sense upon the amount of rainfall, or whether it will be the fuels of the future that will determine the point to which the race can advance is open to argument. Indeed there may be many factors which will have important relations to the future progress of the race; but, so far as we can now see, world activity, as we know it, would cease altogether if fuels and other sources of power were to be denied us. A few years ago, a statesman said that the nation possessing and using the most coal would dominate the world. To-day we know that world power will belong to the nation which uses that coal to the utmost advantage. The difference between these two points of view is one of pure and applied chemistry.

The employment of chemistry in the promotion of true conservation is demonstrated no more clearly elsewhere than in the field of power. Advances that have been made in increasing the percentage of the energy stored in fuel into that which would do work in the form of steam have employed chemistry to a large

extent. In the efficient burning of coal there will be very little, if any, carbon monoxide found in the flue gases; but there will be a comparatively large percentage of carbon dioxide. With the analysis and appreciation of what the temperature of exit gases indicate came the first scientific control of firing. The management could tell by the percentage of carbon dioxide whether or not the fuel was being properly utilized. Early in this work, samples were taken for analysis by chemists through capillary tubes let into the stack at a point where the gases had cooled somewhat and later these lines were extended to the laboratory where, with an aspirator bottle or other suitable means, a representative sample of the gas could be brought into the gas analysis apparatus. Here the carbon dioxide was absorbed in a potassium hydroxide solution and the gas remeasured, that the shrinkage might show percentage by difference. With the increase in importance of checking this constituent of flue gases there came to be devised automatic carbon dioxide or CO_2 recorders. These keep a faithful and permanent record continuously and indicate at a glance the performance of the heating plant.

It is to the chemist that we look for the proximate and ultimate analysis of coal and the determination of the melting point of the ash, as well as a measurement of the heat units that can be derived by burning a pound of the fuel. From the chemical analysis much can be learned as to the value of coal as a fuel, the chemist reporting the amount of volatile matter, of ash, sulfur, and other constituents which experience and laboratory experimentation have shown to have a bearing on the matter. It is comparatively recent procedure to inquire concerning the melting point of the ash; but it has come to be known that the extent to which the ash may fuse on the grates and form clinkers should be one of the determining factors in selecting the fuel.

While many users of coal apply every bit of data the laboratory can furnish in the effort to secure heating value at the lowest possible cost, there are many who depend almost solely upon

the heating units or heat value of the coal. In the metric system the calorie is the measure of heat, the small calorie being the amount of heat required to raise the temperature of one gram of water 1° C. The large calorie is that amount of heat which will raise the temperature of a kilogram of water 1° C. In America the English system is the one employed. It seems unfortunate there should be two systems of heating units, just as we have at least two well known scales for measuring temperature. But somehow the English-speaking peoples have been discouragingly slow in adopting metric units, although scientists and many others are constantly urging such reforms. The British unit is designated the British Thermal Unit, commonly called B. T. U., and is the amount of heat required to raise the temperature of one pound of water 1° F. It is not surprising that many of those interested in fuel have been slow to accept the value of the chemist's work in determining heating units. The story is told of one user who, upon being shown the laboratory report indicating a certain number of B. T. U.'s per pound of coal, angrily pounded his desk and said, "What we want is not B. T. U. but heat in our coal." The term is well known and is to be found in most reports on fuels and in the specifications of all those who buy quantities with care.

Where the coal or coke made from it is to be used in chemical and other industrial operations, the presence of other elements is important, for they may form undesirable compounds, give rise to impurities difficult to separate from the mass, and otherwise embarrass the operations. The presence of such things as sulfur is of no consequence in many heating plants and occasionally the traveler is of the opinion that all the sulfur bearing coal is being burned on the railways.

As has already been indicated, there is much more to the efficient use of coal than burning it upon the open grate fire where but one or two per cent of the heat is made available to the room or even in furnaces where an only slightly larger percentage of the energy is converted into sensible and radiant heat. One of the first to regard coal as a raw material and to

turn it to some more practical use was William Murdoch, who began experiments at Redruth in Cornwall, England, in 1792. He was imbued with the idea that from some carbonaceous material he should be able to distill off gas and this he conceived to be a far better illuminant than anything available in that day. He tried wood and peat, as well as coal, tested the gases distilled off, and considered the economies of the whole operation, comparing the cost with that of oil and tallow as materials for illumination. After lighting his own premises for some five years, he arranged what was considered a brilliant illumination of the works of a firm where he was employed. In 1809, another investigator, Winsor, lighted a portion of Pall Mall with gas which was the first street ever to be so lighted. It was not easy to obtain leave to lay gas pipes in the streets of London, for as may well be imagined those unfamiliar with the process feared lest it was all nothing more than a scheme to blow up the city. By 1813, the London Westminster Gaslight and Coke Company had been formed and within two years had erected three gas plants and laid fifteen miles of street mains. Once again the business of manufacturing such gas grew by leaps and bounds so that two hundred companies were in existence throughout the United Kingdom by 1830. This original company is still in business and is now known as the Gaslight and Coke Company.

Notwithstanding the advent of electric illumination and other competitors of gas lighting, the business of existing gas companies has grown enormously, for to-day gas finds wide use as a fuel not only for domestic use, but in all sorts of manufacturing enterprises. It will be recalled that in the manufacture of artificial or city or illuminating gas, as it is variously called, coal is heated without access of air in earthenware muffles or retorts. The gas is led through purifying boxes where iron oxide mixed with shavings removes the sulfur bodies by combining with them to form iron sulfide. The gas is otherwise cleansed and scrubbed and until recently enriched with the vapors of hydrocarbons or with water gas. The latter is made

by forcing steam through coke or anthracite coal heated to incandescence when the water is decomposed, forming, with the fuel, hydrogen and both carbon monoxide and carbon dioxide. Two or more such beds are employed so that, while one is used to decompose the steam, others may be heated with the aid of a blast to prepare them for the steam. The principal by-products from the average gas plant have in the past been coke, iron sulfide, perhaps some ammonium sulfate, and some tar. No effort was made really to recover the products of considerable value formed when coal is distilled.

For a long while chemists have pointed out the tremendous waste incident to the operation of the beehive coke oven, large installations of which were formerly found in coal districts, particularly those adjacent to steel mill centers. The beehive coke oven is named for its shape. The coal was introduced and burned to coke without the slightest attention being given to anything but the coke. The war more than anything else helped to change all this, notwithstanding the fact that previously some by-product coke ovens had been established in the United States. At first, the blast furnace superintendents would have nothing to do with coke from by-product ovens, for it lacked the silvery luster characteristic of the coke with which they were familiar. It has required the investigation of chemists and metallurgists to prove that in the by-product coke oven coke of a more uniform grade can be made than in the beehive oven and to-day from 70% to 80% of all our coke is made in such ovens. Owing to the low investment in the beehive coke oven and the large initial cost of the by-product oven, it is expected that the beehive will be used for peak loads and in emergencies for many years to come.

The development of the by-product coke oven has involved intense research upon refractories, the charateristics of coal and the changes it undergoes during coking, and a study of how to shorten the coking cycle. By this is meant the number of hours the coal must be retorted before the retort can be reopened, the coke removed, and the retort again filled with bituminous coal.

In recent installations this time has been reduced to eleven hours because the use of silica brick in place of fire clay made possible higher temperatures, while the use of narrow chambers or retorts has made possible the shortening of the coking time. Some coals upon being heated in a by-product coke oven expand, making it practically impossible to remove the coke formed from the chamber. The temperature at which the process is carried out and the general manipulation of the oven has a direct bearing on the proportion of the final products. Perhaps the coke is to be the principal product. Maybe it is the gas from the ovens or again the coal tars now highly valued because they are the basis of colors, pharmaceuticals, explosives, photographic chemicals, perfumes, insecticides and fungicides.

The objection to soot, which accompanies the inefficient burning of bituminous coal, is one of the factors which has made anthracite so popular as to draw heavily upon our reserves of this fuel. Frequent labor differences in the anthracite field, the fact that the supplies are concentrated in practically two states of the Union, giving rise to long freight hauls, and the increased cost of anthracite, have invited the attention of investigators to possible substitutes. In the minds of many, the by-product coke oven offers the best solution. Such an oven can be erected near a consuming center; the gas not required for the operation of the chambers can be turned into the city mains; the ammonium sulfate can be recovered for use as a fertilizer; the coal tar can be disposed of as such or distilled for its toluene, benzene, naphthalene, and other derivatives; while the coke can be crushed, screened, and graded for the city's use.

After all, it must be remembered that perhaps the greatest offenders in besmirching the modern city are the average householder, the apartment building, and the small factory, where sufficient care is not exercised in the proper burning of the fuel and where such devices as can be recommended for smoke abatement have not been installed. Any one who observes the rapidity with which a new building loses its pris-

tine beauty cannot fail to realize the desirability of smokeless fuels.

Among the devices for securing this result has been the mechanical stoker, whether overfeed or underfeed, types of heating plants for apartments and the like with underfeed or similar devices so that the carbon driven off by heating the coal is consumed in the fire zone before the gases pass from the stack, and the use of powdered coal. The latter system of burning coal is applicable principally to large installations. The problems in storing powdered coal in any quantity are serious, for carbonaceous dusts when sufficiently fine and suspended in the proper mixture of air give rise to the most terrifying and destructive explosions. Ways have been devised to minimize this hazard in the use of powdered coal; but the safest way has been to pulverize the fuel on the premises and keep little in storage. Powdered coal burns with a long flame not unlike gas and permits so high an efficiency as to be a competitor with fuel oil. Over 90% efficiency has been obtained with this fuel in regular operation.

Coal has been found to be the source of so much that is valuable that it would almost seem it should be considered as a raw material and thoroughly worked for these values before being passed on to be consumed as fuel; but there are some undesirable constituents in coal which give rise to a great deal of extra work and some trouble. No one wants a coal high in ash and particularly if this ash fuses at a low temperature. One inventor proposes to apply the principles of oil flotation to the treatment of coal. By such a process even fine coal dust might be treated, for applying the principles of oil flotation the fine coal can be collected and skimmed off in the froth, the heavier impurities remaining in the water. In one process oil up to 20% of the weight of the coal is added and, after agitation, the particles of coal in the oil are found as a plastic mass called an amalgam. The coal and oil may be separated or, as is being practiced in one American plant, the amalgam may be pressed into briquettes which are wrapped in paper on automatic machines, affording a clean domestic fuel, ash

free. In another process the ash content is reduced some 75% by a process of cleaning the coal through agitation in a mixture of sand and water having a gravity such that the impurities sink while the coal floats away. These flotation methods and the several cleaning methods may not come into their full significance until our coal supplies are still further depleted; but in most coal districts there are great piles of waste that may some day be treated by a modification of present day methods with great profit to the operator and benefit to a people then casting about for any means by which the fuel supply may be prolonged.

When a comparatively pure coal is carbonized, it is converted into coke, gas, and tar of much higher value. Whether in fact this process will be operated principally for the sake of a smokeless fuel or with a view to supplementing diminishing supplies of petroleum remains to be determined. At present, however, much attention is being given to the low temperature carbonization of coal, for at temperatures around 1000° F. approximately twice as much liquid fuel can be secured as with high temperature carbonization. None of the processes so far proposed have proved commercially satisfactory; but in the absence of methods for successfully coking certain grades of coal by established methods, it is not surprising to find investigators laboring with a problem of coking such fuel by steps which now indicate low temperature carbonization as the probable solution.

The gas producer is a device in which different types of fuels are used for the production of gas of so low a heating value as not to justify storage or any considerable transportation. These producers are usually installed for such plants as glass and steel works where great volumes of gas are required over long periods of time.

Any one must be struck with the fact that literally thousands of men spend their lives following coal around. It is mined, prepared for shipment, delivered to a jobber or a wholesaler, who turns it over to a retailer, who distributes it to the

consumer, and here the next procession forms for the collection, transportation, and final disposition of the ash. A fair proportion, about one third, of the coal mined must be used to transport the balance to the industrial plant and the domestic fireside. It is not surprising, therefore, that many minds have directed their attention to simplifying what seems to be an unnecessarily cumbersome scheme. These plans for superpower go so far as to suggest burning the coal in situ, so that even the mining operation might be saved, not to mention the utilization of much coal which must now be left in place to enable a mine to be operated. Generally, however, these schemes, so far as utilization of coal is concerned, involve burning the fuel at or very near the mine, converting the energy which is chemical into electrical energy, which, when once the power lines have been installed, can be transported quickly, easily, and cheaply. If only a way could be found to finance the electrification of all our railways, scientists believe that such great economies would be effected as to fully justify the enterprise. Rushing through the air as it does, the best of our locomotives shows low efficiency in utilizing the chemical energy made available when the molecules of coal are reduced to atoms. If, instead, this conversion could take place under ideal conditions in a modern power plant with the latest boilers, turbines, and other equipment an undoubted economy would be effected; but electrical installation on this magnitude has not yet been brought to the low price that would make the plan one of actual saving.

Wood cannot be considered a fuel of the present, much less of the future. It can only be of local importance. Advances have been made by chemical engineers in the use of "hogged" or chipped wood, and one of the nicest bits of research has made possible the utilization of lignin resulting from the pulping of wood by chemical processes under the plant boilers. It was first necessary to design a new type of evaporator and to devise, as well, a plan for burning the concentrated liquor in a way to enable the recovery of the soda which it carried. But

in a single installation this has been done so that to-day there is available 1200 horsepower daily in excess of the energy required to evaporate the spent liquor carrying the lignin and the sodium salt.

With the number of registered motor vehicles in the United States alone approaching 20,000,000, with the fleets of motorboats and other aircraft driven by internal combustion motors, with one single factory producing 150,000 farm tractors annually, and many small manufacturing plants and farmers using stationary gasoline engines, one might almost look upon liquid fuels for internal combustion motors as the source of most importance at the present time. The combined horsepower of such engines of all classes undoubtedly exceeds the combined steam horsepower of the land and very probably at least equals steam power plus hydroelectric power. If the chemist can be shown to have contributed something to increase the supplies of these liquid fuels, his claim to participation in making power available will be valid indeed.

It seems incredible that within the memory of living men the producers of kerosene made such an effort to work off their gasoline surplus in the kerosene as to require standards to be established for the safety of the consumer. To-day there is need of standards to protect the temper and the pocketbook of the motorist who believes these same oil men now desire above all things to work off on him as large a percentage of kerosene as possible in the gasoline. In the good old days when gasoline was under ten cents a gallon, most of the crude petroleum was merely topped, that is, it was distilled without much regard for the percentage of gasoline separated and as gasoline and some of its close relatives are the low boiling fractions of crude petroleum, these came off first and hence the term topping. Had the industry been content with this simple method of distillation, our supply would long since have been found wholly inadequate. The chemist began "cracking" experiments by which is meant taking apart the large molecular structures characterizing petroleum so that simpler bodies would be

formed and the percentage yield of gasoline thereby increased. It was found that under certain temperatures and pressures a fair degree of cracking could be obtained. By the old process of topping, some 10% to 15% of gasoline was obtained. The earlier cracking processes gave two or three times that amount. With that as a beginning there have been many modifications, most of them devised to eliminate the fire hazard always present when an inflammable substance is heated under pressure, and to learn ways of lowering renewal costs of apparatus by carrying on some of the most destructive operations in detached replaceable units. The physical chemist has come into the picture and gasoline yields have been steadily pushed forward into the sixties and perhaps an even higher percentage. Presumably the petroleum technologist will not be wholly suited until he is able completely to change petroleum into a motor fuel.

These investigators have also contributed immensely to the problems of preparing satisfactory lubricating and transformer oils, in making the greases and wax from residues for special purposes, in finding applications for petroleum asphalt and coke from the crude oil stills, and generally seeing to it that any by-products find a profitable market. Chemists have also played their part in avoiding losses. It has been recently announced that black tanks absorb and hold heat rays, thereby causing the gasoline stored in them to expand, vapors to be driven off, and these are usually lost. The painting of oil tanks with aluminum paint, therefore, not only beautifies the tank, but actually reduces by a substantial amount the losses of gasoline vapor from such storage houses. More recently a chemist has devised a special coating for canvas or other cloth through which gasoline vapor does not penetrate. Cloth so coated remains flexible for a long time. This cloth is made up into great bags known as breather bags placed in a house apart from the storage tank. When the temperature increases and vapors are thrown off by the gasoline, they do not escape into the air as formerly but pass into the breather bags from which

they can be collected as liquid when the temperature is lowered again. This device in the hands of one great company alone is expected to save during the summer season at least a million gallons of gasoline per week.

It is to be hoped that from the standpoint of natural resource conservation it will be many years before oil shales must be worked for their petroleum content. There is a certain gratification, however, in knowing that in the United States very large deposits of oil bearing shales are to be found. Quoting from the monograph on Shale Oil, by R. H. McKee and others, "The great size of the oil shale deposits of the United States is not generally appreciated. The United States has furnished and is furnishing about two-thirds of the world's supply of petroleum. Since the discovery of oil in Pennsylvania in 1859, about eight billion barrels of oil have been taken from the petroleum wells of the United States. The oil shales of the Green River formation in Colorado and Utah alone can furnish fifteen times this amount of oil. If we add to this the oil reserves in the form of oil shales in other states we have a total potential shale-oil supply greater by twenty times than the total oil that the oil wells of this country have yielded in the past sixty years, and this without considering shales which produce less than 30 gallons of oil per ton." [1] These oil shale deposits are looked upon as reserves; but in the interim prospecting goes forward. The technology is being worked out, and when the economic situation demands, shale oil can be drawn upon. The process by which shales will be treated when that time comes will be one based upon the chemical considerations involved.

From petroleum wells there comes a gas known as casinghead gas, which for many years was discarded and wasted. It was then found that if this gas could be condensed it would be useful in motors, and so the condensation and absorption of casinghead gas became a problem for the chemist and the mechanical engineer. The result has been the addition of many

[1] Page 14.

millions of gallons of useful fuel to our annual supplies. In some processes the casinghead gas is absorbed in a petroleum oil under pressure and is later distilled out, giving a very volatile liquid which must be blended with others before it can be stored or used to advantage. In some instances, compression alone is used; but this has not proved so satisfactory, and both processes have been somewhat superseded in more modern plants where activated charcoal, a child of the war, is used to absorb the desired higher hydrocarbons found in casinghead gas.

Some natural gas wells also contain higher hydrocarbons and the gas is known as wet gas. The gasoline from these two sources amounts to about 900,000,000 gallons annually.

All of these sources of fuel have been left to us by a very ancient past, and so far as we know new deposits are not being laid down for posterity. It is quite natural that the subject of an annually grown fuel should attract the scientist. He turns to the annual crops which store up energy in the form of cellulose or wood, starch and sugar, all products produced by the plant at normal temperatures and pressures with the help of the sun, the chlorophyll, the carbon dioxide of the air, water, and a very small fraction of the soil constituents where the plant grows. It is true that measurements show the plant to be only $1\frac{1}{2}\%$ efficient but so far man has not been able to devise a way successfully to produce on a competing basis the product stored by the plant. Alcohol, which we make from corn, from potatoes, and waste molasses, is used alone or in mixtures for propelling automobiles in some localities. The ferments which change the starch of the corn and the potato, especially grown for the purpose, and the sugar of the molasses into alcohol work for a very low wage and demand only that optimum conditions of food and temperature be maintained. The difficulty from a fuel standpoint comes in distilling the weak solution of alcohol formed to obtain the higher concentation. It may even take as many B.T.U.'s to concentrate and purify the alcohol as will be found in the finished product; but sight must not be lost of the fact that in its new form it may be far more useful than

the energy in the solid forms of fuel used in the process. The alcohol forms the starting point of a chemical process resulting in ether, which may be mixed in certain well defined proportions with the alcohol. The alcohol may also be used with the gasoline only, however, in case it is absolute alcohol, a term applied to the liquid free from water. If lower grades of alcohol are used, other materials such as benzol and ether must be used to secure a satisfactory blend.

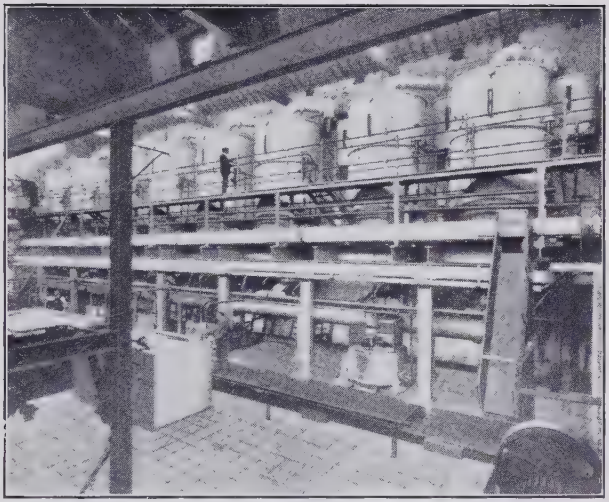
C. F. Kettering, the prominent automotive engineer, states that about 5% of the energy of petroleum is now used in the modern motor car. Higher efficiences depend upon the design of the motor in which greater compression is employed; but greater compression with gasoline as a fuel gives rise to knocking, a phenomenon in a motor which no driver enjoys. Mileage might be even doubled per gallon of fuel, if engines were designed for higher compression and if fuels which would not give rise to knocking were available. The incentive to discover what are called anti-knock compounds is therefore great. Much research has been done upon the problem, and one after another compound of anti-knock properties has been evolved only to be discarded for something better. For two or three years, the compound tetraethyl lead in a solution having present an organic compound or salt of bromine has been used with marked successs. The performance of this compound as an anti-knock agent is highly satisfactory and when present even in traces the effect upon the engine is most marked. The increased demand for the material brought about a serious difficulty in the bromine market and led to a thorough search of the world for new sources of bromine other than the salt wells of Michigan. The sea was known to contain about .007% of bromine; but no process had ever been devised for recovering such small traces of an element. One was devised, however,[1] which was given a semi-commercial scale trial just before the decision was reached to withdraw the material from the market pending further reports.

[1] *Supra*, p. 14.

Chemistry plays an important part in another field of power. Not only does it assist in preparing the materials with which hydroelectric power plants are built, but with its help the important lubricating oils, without which no power plant can run, are provided. In one American installation, a lignum vitæ bearing has been constructed for the purpose of minimizing the oil required; but this solution, even if successful, could not be applied to all parts of the mechanism.

The last year or two has seen chemists, chemical engineers, and others endeavoring to find still more efficient ways for using fuel. Abroad, one investigator has succeeded in devising a burner which permits oil actually to be burned in water. Water immediately in contact with the flame is converted into steam and naturally there is none of the loss for which boiler walls and insulation otherwise account. Gas may also be burned under water. The tendency of the laboratories is toward temperatures and pressures considered impossible a few years ago, and one installation is actually operated at the critical temperature of water so that under pressure the water passes directly from a liquid stage to steam without going through the vapor stage. The efficiencies under such conditions fully equal the theoretical. At least one plant in the United States is giving a thorough test to the mercury boiler, a plan which seeks to take advantage not only of the greater heat which the mercury vapor can carry, but the use of the superheated vapor in a turbine, after which the heat is given up to water for the formation of steam, the combined steps giving a much increased return for the fuel consumed. Experiments have also been conducted with diphenyl ether and with sulfur dioxide as the medium along the same lines.

But what will chemistry do to provide fuels in the future? The low temperature carbonization of coal has been mentioned. There is another plan for the complete gasification of the coal. In this the coal is converted into coke by the sensible heat of the hot producer gas in the top of the retort, while the resulting hot coke is converted into producer gas in the lower zone of the

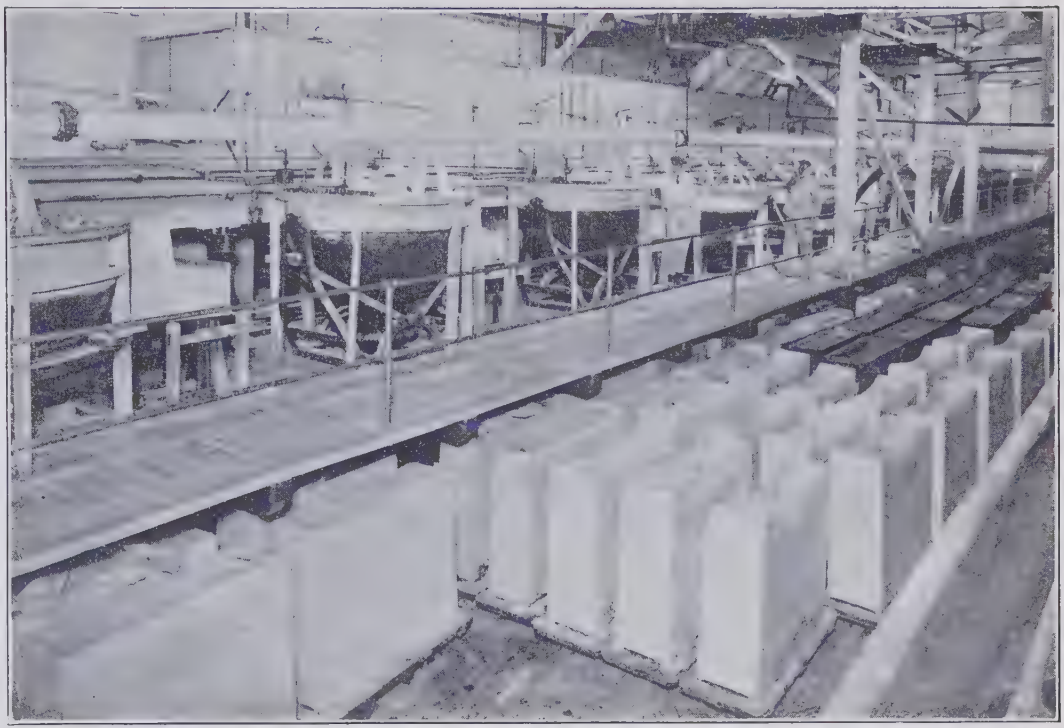


A Glycerine Recovery Plant.

Showing multiple evaporators with salt extracting and conveying equipment. Glycerine is a highly important by-product of the soap industry, at times commanding because of its use in the chemical industry a price equalling if not exceeding that of the soap itself. (Courtesy, Drug and Chemical Markets.)

ROWS OF GIANT KETTLES IN ONE OF THE LARGEST OF THE WORLD'S SOAP FACTORIES.

Such kettles are two or three stories high and are provided with an elaborate series of piping, which brings oils and fats, alkali, water, steam, or whatever else may be required. Soap kettles hold from a few thousand to more than a million pounds of soap. (Courtesy, Procter & Gamble Co.)



"Crutchers" in a Great Soap Factory.

These are types of mixing machines which play an important rôle in the production of fine soaps. Blocks of soap on small wheeled trucks are shown in the foreground. Liquid soap is run into iron forms which are lifted after the soap has cooled. (Courtesy, Procter & Gamble Co.)

same apparatus, this being a distinct gain over a two-step process, in which the sensible heat of the hot coke is lost. Prominent among those engaged in research upon fuels is the work of Bergius, in Germany, who has contrived a method for converting the greater part of coal into liquid fuel. He heats pulverized coal and petroleum to 700° F. in an atmosphere of hydrogen under a pressure of 200 atmospheres per square inch. Under these conditions most of the coal is converted into liquid products. Another investigator has worked with water gas under similar high pressures, using a catalyst, preferably iron coated with potassium carbonate, and as a result gets a synthetic oily liquid that can be used in motors. The year 1925 saw a good part of the world interested in synthetic methanol made by a process similar to that for fixing atmospheric nitrogen as ammonia. While experiments on the relative efficiency of methanol as compared with other motor fuels has not been completed, the liquid has been used in internal combustion engines and may prove to be the source of much of our power in future. However, it is better to look upon it as the first in a series of progressive steps that must be taken, if we are to convert the forests of the past into the fuels of the present. The production of the necessary carbon monoxide and hydrogen can be accomplished with many sorts of solid fuels, and synthetic methanol, therefore, may be found to be only the forerunner of an even more important fuel made from solids by chemical methods of catalysis.

There still remains for consideration among other things the question of using atomic energy. Most of us have done well to comprehend what is meant when we say that in burning coal the energy derived is that due to the breaking down of molecules into their component atoms. Now it is proposed that we go a step further and reduce these atoms to their electrons, for it is known that an atom is held much more firmly together than a molecule and there is consequently more energy at our command if ways could be found to get at it. We have no real conception of atoms and their component parts. The numbers

become too great to be really significant. Doctor W. R. Whitney, in Industrial and Engineering Chemistry for September, 1925, endeavors to state the proposition in a way which will give at least something for comparison. He says: "The actual smallness of an atom is impossible to realize; but so much seems known about its dimension that we must accept and try to apply it. A molecule of water contains two atoms of hydrogen. Suppose we start with one single drop of water and let all its hydrogen atoms appear in turn as drops of water. How much of a rainfall must we picture in order to visualize all these hydrogen atoms of that drop. We know that the drop contains about 3×10^{21} hydrogen atoms. If these were as large as raindrops, they would cover the whole world with a foot of water." No wonder, then, that if we could utilize the energy which holds together the atoms in a teaspoonful of water, there would be sufficient to drive a 20,000 ton vessel over the seas for a long period of time. No wonder that one scientist stated he hoped the way to use atomic energy would not be discovered until the race had developed to a point making it safe to place in its hands such inconceivable power. There seems no likelihood of the early application of atomic energy on a commercial scale; but it is never safe to predict in science, and especially hazardous to predict that a thing will not be done.

The interest in fuel technology, in methods for increasing the supplies of fuel, in processes for the production of satisfactory synthetic fuels as liquid from solid, the schemes for transporting power in the form of electrical energy with its consequent saving, and all the other enterprises that look toward prolonging the period of our high state of civilization by supplying adequate energy, will become of increasing interest in future. If the future is to enjoy anything like the civilization of the present, we must make constant and continued investments in our chemical research. Perhaps a civilization depending upon some other consideration more than power may be developed; but that, like the size of the atom and its component parts, is at present beyond our comprehension.

Chapter XII

THE ABOLITION OF DRUDGERY

What an enormous amount of work has been done on the earth and what vast undertakings mark each new year! Practically all work was at some time drudgery and much work will always be hard or unpleasant. Since the cost of most things bears some relation to the amount of labor expended in its production and distribution, those items calling for the expenditure of much work are available to those able to pay for the labor and all that is involved with it. As drudgery has disappeared and as labor has been lessened, commodities once worth a king's ransom have become everywhere available even to those in the most moderate circumstances. To-day, thanks to the achievements of science, the difference between the wealthy and those not so well-to-do is one rather of luxuries than of necessities.

Even the present drudgery of the world would be far worse but for the help of that same chemistry which has been useful in abolishing so much of it. Of course, it cannot be properly claimed that chemistry alone has lessened the world's drudgery, for all the natural sciences have had a part in this task, as they have in nearly all the other things discussed in this volume. Chemistry is a fundamental science, for, as frequently emphasized, it deals with the changes which matter undergoes as temperatures, pressures, and concentration are changed and various forms of matter are brought into contact with each other. The mechanical engineer can point to ever so many achievements in his field without which we would scarcely know how to manage; but it might be argued from a narrow point of view that his work would be impossible but for the materials out of which he contrives machinery that does

practically everything but think, and since the production of these materials involves changes in matter, chemistry is represented. But appreciation can be expressed for the achievements in fields commonly allocated to other sciences without going into detailed discussion.

Elsewhere a few facts regarding energy and power are presented. We have learned how to adapt mechanical devices driven by the energy of domestic animals, by steam or by electricity to an almost unbelievable variety of tasks previously listed as hand labor. Man might have eventually conquered the temperate zone without the assistance of the domesticated horse and ox; but certainly the utilization of these animals is considered one of the greatest contributing factors. The inability to use these animals in the tropics has greatly delayed the industrial conquest of those rich lands, a conquest which may now be made due to the forward strides in sanitation and means for combating tropical fevers and diseases and the perfection of the light weight internal combustion motor, which will save man even more work than does the employment of the horse or ox.

In a very proper sense, domestic animals are converters of energy, the metabolism of their bodies converting the energy stored in the chemical compounds — cellulose, starch, sugars, and protein into a form of energy which will do useful work. As has been pointed out elsewhere, the steam engine does its work because of the utilization of chemical energy through burning fuel to convert water into steam, and the internal combustion motor does its work as a result of a chemical reaction so violent that the wonder is, explosions occurring with great rapidity in the cylinders of the engine do not cause destruction. The mastery and control of these explosions is one of the wonders which has done so much to abolish drudgery.

It is doubtful whether the work of the world as we know it could possibly be done wholly by manual labor. It is true that, so far as we know, enormous loads were managed by manual labor in the construction of the pyramids; but to-day

even an Egyptian Pharaoh or Crœsus could not lavish the labor of hundreds of thousands of human beings on such an enterprise or any other.

Agriculture affords a good example of what can be done by reducing the amount of labor and by increasing productivity by the application of chemistry. During the last generation there has been a fairly steady stream of people away from the farms to the villages, towns, and cities, where the type of life that is more appealing can be led, even at the sacrifice of much freedom which characterizes rural life. Concurrently there has been an increase in population with its accompanying increase in the demand for foodstuffs, and while transportation has developed with the aid of science to the point where food may be brought from far and near, it nevertheless behooves the American farmer to maintain and, if possible, increase the production of his fields. We have, then, an increased demand to be met with a decreasing number of laborers. Oddly enough, notwithstanding this, we frequently have an actual local overproduction of food crops. These may be said to be due to improved methods of agriculture largely discovered through the work of agricultural experimental stations to be found in every state of the Union, to an increasing knowledge of soil and how to handle it, to a better understanding of the food requirements of plants, and to the achievements of the chemists in providing from natural sources or by synthesis these same plant foods. Improved farm machinery and the introduction of the gasoline motor into farm work is the rest of the story.

The ever widening network of improved highways, the success of the rural free delivery of mails, the installation of the party line telephones satisfactory except when too many neighbors endeavor to listen in, the automobile for quick and easy travel, and now the radio offer a combination which should gradually win back to the soil numbers to make up for earlier losses in farm population. These will find farm life very different, and these changes have led James J. Montague to compose the following lines:

TIMES HAVE CHANGED

Ah! happy the farmer who lolls on his plow,
Content in his face and with clothes like an actor.
No walking the furrow for husbandmen now;
The whole of his labor is steering the tractor.
There weren't any tractors when I was a lad,
I rose from my bed when the dawnlight glowed pearly,
And a wearisome tussle till darkness I had —
I got here too early.

Serenely the milkman now summons his kine,
A tiny electrical motor he throttles,
Then he twiddles his thumbs till a quarter past nine,
While the milk is withdrawn and collected in bottles.
They didn't milk cows by mechanical means
When I was a youthful and laboring hick,
I milked fourteen cows, in my tattered blue jeans —
I got here too quick.

The gardener rolls on through the fast-flying grass;
A canvas umbrella provides him a bower,
He shifts a few levers and turns on the gas
And cuts a whole lawn in the half of an hour.
I pushed a lawn mower — and I pushed it blamed hard —
I recked not a whit of this wonderful boon,
And dropped from fatigue when I'd finished the yard —
I got here too soon.

No low-humming motors, no gas-driven wheels,
Made easy my labors when I was a boy,
Enabling me idly to kick up my heels
And figure that life was one long dream of joy.
I went to my slumbers disgusted and worn,
I quit the farm early — and took up with rhyme. —
I am not a farmer, because I was born
Ahead of my time.

The telephone companies of the country carry some 20,000,000,000 communications a year or something more than one message every day for every man, woman, and child in the country, remembering that each message involves two persons. The distance covered by these messages will probably approach 50,000,000,000 miles. Suppose this service were undertaken by messengers and suppose that each messenger should work nine hours a day and be able to make the high average of ten miles per hour, it would require nearly 7,000,000 messengers to do the work and the cost at a conservative estimate would approach $11,000,000,000. Consider by comparison how easily this work is done by the 300,000 employees of the telephone companies connected with some 25,000 central offices and 17,000,000 telephone instruments, the whole representing a cost of a little more than $2,000,000,000 and handling the business at a twentieth of the cost, even if we were able to use so large a proportion of the working population as would be necessary for our messengers.

Our civilization has become so nearly a paper civilization that the consumption of paper for various uses has been suggested as a measure of that civilization. Refer for comparison to the information on page 22. Suppose, for example, that all this paper had to be made by the primitive methods where one sheet would be formed at a time upon a hand screen such as is still used in making certain grades of fine Chinese and Japanese paper, it is obvious that a disproportionate number of the working population would be required to meet the present need.

The history of drilling holes in wood and metals is interesting as showing this constant trend away from drudgery and a speeding up of operations, which means increased production with its accompanying lower costs. The labor and time involved in forcing a flint tipped drill, weighted to give pressure, through a timber by the bow and string process is infinite compared with the modern brace and tempered bit. The string was passed around the drill which was then revolved as the bow was drawn back and forth. In 1924 a drill manu-

factured in Cleveland, Ohio, established a record which again emphasizes the contributions of chemistry. This drill was $1\frac{1}{4}$ inches in diameter and working in cast iron could be driven at 800 revolutions per minute and remove 142 cubic inches of metal weighing 37 pounds during that one minute and while drilling a hole 116 inches deep. No tool other than those capable of working at red heat without deformation of the cutting edge could do such work and alloys with such characteristics were unknown before the days of modern chemistry. In the days of ancient Egypt, the work in the hard basalts, granites, and other dense stones was done with soft iron tools, if the relics of the civilization are to be taken as a guide. It was only the use of great numbers of such tools constantly kept sharpened by an army of assistants that enabled the work to be done. As has been mentioned elsewhere, the ability of science to provide metals of great strength capable of being machined, rather than ground, is another example of the point which we would emphasize.

An excellent example of time saving which contributes directly to costs and lowers the prices of products, which in turn can save labor, is to be found in the story of the acceleration of rubber vulcanization. To do with the aid of organic chemicals a work in thirty minutes that formerly required from two to three hours speaks for itself. Electricity has been a great boon to the laboring world and few industries employ chemistry to a greater extent than does the electrical industry. "Consider an average factory, employing, say, one thousand workmen, in which the machinery is driven electrically. The power consumed in driving is perhaps equivalent to the labor of twenty thousand men who by virtue of a distant steam or hydroelectric plant appear on the payroll of the factory only to the very small extent of perhaps ten dollars or so per man per year. The one thousand workmen actually employed are then virtually directing the labors of twenty thousand others. Each of these one thousand workmen is serving in a foreman's capacity, directing the labors of twenty others. He is there-

fore receiving not only a foreman's wage, but he is also profiting by the cheap hire of the twenty electrical workmen whose efforts he is in effect directing." One authority has said that a slave-power year, considering the proportion of time the average man is able to work and the present price of electrical energy, now costs between four and six dollars.

We merely push the button and we get light, heat, and power brought from a distance, (and no doubt in future as we perfect methods for transmitting higher voltages economically from greater and greater distances) that those in the home may enjoy modern electrical appliances which lighten the wash day, the ironing day, the cleaning day, in fact, every day in the routine of housekeeping. When the chemist and the physicist succeed in perfecting the right type of storage battery, this convenient form of energy may be more widely and more cheaply available. A proper storage battery would enable the operation of a hydroelectric power plant, for example, on a twenty-four basis. When the current was not being used in homes and factories, during wakeful hours, it could be directed into the storage batteries at a very low cost and drawn upon as needed.

By the use of carbon dioxide, ethylene, methyl bromide, ammonia, and other compressible gases, with or without brine, the chemist proposes to assist the refrigerating engineer in spreading the benefits of iceless refrigeration, particularly for the household. With these devices at a price to encourage wider distribution, there will result not only a saving of labor, but of annoyance as well and probably the safeguarding of food supplies. In explosives we have stored chemical energy of the greatest use in removing drudgery from many of our peace-time activities. Eighty thousand workmen required seven years to quarry the pure white stone used for Solomon's temple. Bronze or soft iron picks were used to mark out the dimensions of the blocks in the quarries, and into niches cut in the stone dry wooden wedges were hammered, water poured upon them, and the swelling of the wood depended upon to crack out the

block. It required many days of labor at a cost that would paralyze modern industry for King Solomon's workmen to do what one pound of dynamite can accomplish in a moment. Not long ago, in Wisconsin, 250,000 tons of rock were blasted down with 32,200 pounds of dynamite or nearly eight tons of stone for each pound of a raw material, the usefulness of which depends upon chemical energy.

In the days when Hiram, King of Tyre, dictated the metal markets of the world, the Rio Tinto mine in Spain, which is still in operation, supplied much of the silver. Forty thousand workmen could produce three tons of silver annually. In a recent year in the same mine, two and one-half million tons of ore were taken out by 9,000 men working with modern explosives.

In the days of Claudius, 30,000 men labored for eleven years to drive a single tunnel three and one-half miles long beneath Monte Salviano. To-day the Hetch Hetchy Aqueduct through the Sierras includes 69 miles of tunneling which at some places were advanced 776 feet a month. In other words, the Monte Salviano tunnel, so arduous a feat for the workers of antiquity, could be driven to-day with the help of explosives by less than 100 men in approximately 10 months.

A mechanic once said that if he were to be given the choice of but two tools and then required to demolish a structure, he would prefer the hammer and the cold chisel. The hammer and the cold chisel are still of great utility, as are the hacksaw and other mechanical methods for cutting metals. In this scientific age, however, we prefer very small, but exceedingly hot, gas flames such as those obtainable when the element oxygen and the chemical compound acetylene are burned together under prescribed conditions. Acetylene found its first employment as a source of illumination for bicycle and then for motor car headlights; but its principal task to-day is for this work of welding and cutting metals. When buildings are to be demolished, the steel framework is cut with the oxyacetylene torch. In case of wrecks or other disasters, the wreckage is

quickly cut away with the same tool. Where giant gears or other parts of costly machines are to be cut out of great bars and ingots, it has been found that the oxyacetylene or the oxyhydrogen blowpipe can perform a service beyond the powers of mere metal cutting tools.

The vacuum tube, which is in reality a valve admitting from exterior sources energy of a form that will not distort the feeble impulse to be amplified, presents new possibilities in labor saving and drudgery banishing devices. This is a comparatively new field into which some researchers, already distinguished for results achieved in other fields with vacuum tubes, have entered.

In banishing drudgery, science has helped either to increase production, which lowers costs for rich and poor alike, or to make possible production in a shorter time, thereby lessening the hours of labor. In one great industry the present generation has seen the seven-day week abolished and the eight-hour supplant the twelve-hour day. But with such benefits there comes a new problem, what to do with leisure. The enrichment of life which has come from the application of science, and chemistry in particular, should make it anything but difficult for those who have had no leisure at their disposal to invest to advantage this new allotment of time.

The success in ridding certain industries or parts of industries of drudgery has thrown into relief those where the special activity involved makes difficult the lightening of the work. Ingenuity that can devise machinery for mining thin seams of coal may be relied upon to overcome other difficulties. As scientific work progresses, new theories become established, new methods of technique are developed, apparatus is improved, and one science borrows from the experience of another that which may be of assistance. As a result, old problems that were thought without solution fall before the modern attack, while still others await the results of research in progress. But everywhere there are evidences of less cruelly hard labor and a persistent though gradual extension of the riches of this

life to levels where small incomes heretofore have been a bar to much that is for culture and entertainment. With a further extension of such benefits there should be a decrease in feeling between classes created by differences of wealth, and to such progressive and beneficent work chemistry is proud to contribute its share.

Chapter XIII

CHEMISTRY IN NATIONAL DEFENSE

Reduced to the simplest terms, war is the pitting of the resources of one nation or group of nations against those of another. The side which has the greatest resources or the side that uses its resources to the greatest possible advantage maintains the better position. Any agency, therefore, which makes resources more available or enables the more efficient use of them obviously is a vital military factor. Chemistry, the constructive agency in peaceful industry, becomes upon order the indispensable ally of Mars. The qualifying term "upon order" is used advisedly, for the natural sciences are truly constructive in their work and purpose. The scientist is a peaceful person busy in his pursuit of truth for its own sake or in the application of the data gained through such research to the world's work. He wants nothing more than to be provided with facilities with which he may carry on his studies and with opportunities to apply the data gained through his research. In cases of emergency, however, when called to the national defense, he brings with him a knowledge of the ways of matter which obviously has become indispensable.

The realization that some of the agencies of war have their origin in essentially chemical factories has been seized upon by certain types of propagandists who insist that the managers and directors of such plants constantly plot war somewhere on the earth because there is profit in it. The oldest and largest manufacturer of industrial and military explosives in the United States has repeatedly issued statements which show that the profits of this concern are derived from peace-time activities and that, notwithstanding the wars of one kind or another usually in progress, the actual percentage of the time during the

plant's existence when our nation has been at war is but a fraction of the total time and would never justify the extensive plant which is continuously in operation. This particular company may point with justifiable pride to the low cost at which it supplied explosives to our government in the late World War, the readiness with which it shared its manufacturing secrets that ample explosives might be made by all concerned, the extent to which their engineering experience was shared with the government, and the work done on the recovery of alcohol which represented a saving of millions of bushels of corn at a time when all forms of food meant so much. Companies who are in war for the profits it yields do not practice such procedures.

The processes which gave the ancients the Toledo blade and Damascus steel depended upon chemical and metallurgical principles, although not recognized as such. It is very doubtful whether the inventors of gunpowder knew the chemistry underlying that compound; but it is the first recorded use of chemical substances mixed together for military purposes. The powders of that early day must have been crude and unreliable mixtures, even more dangerous to those who fired them than to those for whom the projectile was intended. Contrast the manufacture of modern explosives, which is essentially a chemical industry founded upon the most careful research and supervised in all departments by highly trained and experienced technical men. The explosives of to-day bear little relation to those original mixtures of charcoal, saltpeter, and sulfur.

Among the modern explosives, picric acid is probably the first chemical body known to have such characteristics. While used many years as a dyestuff, it was not recognized as explosive until 1805, and it was 1871 before it was discovered that picric acid could be detonated with a fulminate of mercury cap. 1846 saw the discovery of guncotton, as well as nitroglycerine, and these two substances form the basis of modern smokeless powder and dynamite. Trinitrotoluol and other nitrated bodies came into their greatest use in the late war. Prior to

that time smokeless powder in its various forms and bearing a variety of long names took first place among military explosives. Schultze is credited with the introduction of smokeless powder in 1865. He used bits of wood, nitrated, and then impregnated with the nitrates of barium and potassium. The next step was the gelatinizing of this nitrated wood by treatment with ether and alcohol mixtures, and this step was the real basis of modern smokeless powder. The first military smokeless powder was invented in France in 1886 and was made by forming a dough of nitrocotton with alcohol and ether, rolling it out into sheets, cutting strips, and drying them. Ballistite was prepared by Nobel in 1888, in which year the British government introduced cordite, which is made by gelatinizing insoluble nitrocotton of high nitration with acetone and nitroglycerine. The governments of the world undertook extensive programs of research following the announcement of these smokeless powders, the United States being the last of the great nations to adopt this material. It was first adopted in America soon after the Spanish-American War. This powder is of the nitrocellulose type, to which is added $\frac{1}{2}\%$ of diphenylamine as a stabilizing agent.

The basis of these powders is cotton usually in the form of linters. Linters are very short fibers which are removed from the cotton seed after the long staple fibers have been removed. The great need for this type of fiber led to improvements in treating the seed so that the fiber could be cut much closer with a substantial increase in its yield. Incidentally, this was the origin of one of the post-war problems of how to consume this larger quantity of linters which naturally the cotton mills wished to continue to sell. As has been pointed out elsewhere, much of it now finds its way into paper pulp, thereby somewhat relieving the shortage of rags for paper making, while increasing quantities are required for the new types of lacquers. The extent to which these lacquers are finding application bids fair to rival soon the demand for linters caused by any war. The first step in the manufacture of powder is to purify the cotton by

digestion under pressure. This removes oily substances, fragments of leaves and hulls, and similar material by the caustic liquor in which the digestion is made. The nitrating proper is done in small batches of approximately 36 pounds in a mechanical agitator using about 1500 pounds of sulfuric and nitric acids mixed. The nitrating time is thirty minutes, after which the mixture of nitrocellulose or nitrocotton is dumped into cold water. After this it is boiled for 40 or 45 hours in slightly acid water and then it is reduced by grinding under water in beating engines. After further boiling, repeated washings, stirrings, and settlings for the removal of unstable products and traces of acid the nitrocellulose is finally run into centrifugals which remove from 65% to 70% of the water.

Having prepared the cotton called pyro nitrocellulose, the production of smokeless powder may be begun. Forty-five pounds of the wet pyro is compressed in a hydraulic press at 250 pounds pressure into a block. Alcohol is now pumped through the block while still in the press, thus displacing the water. Greater pressure is now applied until the weight of the alcohol remaining equals one-third the weight of the nitrocellulose. The block is now broken into small pieces; then it goes to the mixing machines, where sufficient ether is added to make the proportion of solvent one-third alcohol and two-thirds ether, the solvent equaling in weight the pyro to be treated. The diphenylamine previously mentioned is dissolved in the ether, and the mixer, to prevent loss by evaporation of the solvent, is cooled with circulating brine. The colloid obtained by this process is finally formed through dies and granulated on cutting machines into the size and shape of grain required by the several types of ordnance.

Trinitrotoluol, familiarly known as T.N.T., was really introduced to the world early in the great war. Long before, however, the research which led to its discovery was undertaken primarily to reduce costs in dye manufacture where toluol was one of the raw materials. When toluol is nitrated there are first formed two mononitrotoluols, the properties of which de-

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CYANIDE FUMIGATION.

The man in the foreground is measuring the tent-covered tree and calculating the dosage of hydrocyanic acid to be used. The dimensions of the tent are in feet and the tape is marked in feet and inches, while the dosage table is printed on the tape. The man in the background is "shooting" the predetermined dosage of liquid hydrocyanic acid under the tent. The use of the acid in liquid form is a recent development. Formerly sodium cyanide was employed and treated with sulfuric acid in place. The accompanying dangers have been largely eliminated by this more recent method. (Courtesy, Oil Fumigation Corporation.)

Cyaniding Citrus Trees, using Apparatus Designed for Large Orchards.
(Courtesy, Pacific R. and H. Chemical Corp.)

pend upon where the nitro group becomes attached on the benzene ring. Orthomononitrotoluol and paramononitrotoluol differ very little in their molecular structure from the layman's point of view; yet one of these was wanted for dye manufacture but could not be made without so large a proportion of the other being found in the final product as to make the outlook discouraging. Research was undertaken to find employment for the objectionable mononitrotoluol and for a time the scientific press contained references to research in progress. After a time this ceased and interest in the question more or less subsided. It was not until after Germany had a considerable stock of trinitrotoluol on hand that it was found that one of the research chemists had nitrated the mononitrotoluol to the trinitro form and had found it to be a high explosive of terrific power yet capable of safe handling. No one can predict what revolutionary discovery may come out any moment from the test tube, the furnace, or the catalytic bomb.

Picric acid continues to be used as a military explosive, and because it may be depended upon to explode quickly and easily some prefer it to T.N.T., which is safer to handle but occasionally disappointing from the military standpoint. The adherents of T.N.T. point to the occasional disasters due to the unstable nature of picric acid as an additional reason for choosing T.N.T.

There are many variations of the leading types of military explosives, one interesting explosive of importance being amatol, another World War introduction. This consisted of a mixture of ammonium nitrate with trinitrotoluol and is an explosive of tremendous force. Ammonium nitrate itself is used as an explosive, and it was with the manufacture of this material in mind that the construction of the nitrate plants at Muscle Shoals was authorized.

A collection of samples of the military and sporting powders of the world is interesting, for there will be found grains of powder of all imaginable sizes, shapes, and even colors, some manufacturers coloring in particular their special brands of powders for shotgun and sporting rifle. The very large grains

of powder for 16-inch guns, for example, present quite a different appearance from the grains of powder as popularly conceived.

It will be obvious that in the manufacture of explosives there are many difficult chemical problems. There is the manufacture of sulfuric and nitric acids and their concentration, the solvent recovery to which reference has been made, the difficulty of selecting types of apparatus carefully made of such materials as will withstand the corrosion of the contained materials, and always safeguarding employee and property against tremendous hazards. It is difficult for those not experienced in explosives manufacture to appreciate what it meant to design and construct under pressure a plant like that at Old Hickory with the rated capacity of a million pounds of powder per day. The total amount of smokeless powder made in this country was greater than the amount produced by any other country and the rate at which production was increased from the pre-war activity to the high peak of the government requirements was no less than astounding.

Notwithstanding solemn treaties, the late war introduced a new element. While it was recognized that the carbon monoxide generated when a shell explodes frequently caused as many casualties as the shell itself, this was not thought of as chemical warfare. While the chemist had a part in the perfection of ordnance, in the armoring of battleships, and in obtaining such precision in the rate of burning of powder as to make possible the introduction of new military tactics, it remained for the use of gases, such as chlorine, recognized as chemical substances to introduce the term *poison gas* and the designation *chemical warfare*. This is not the place in which to argue the pros and cons of chemical warfare from the standpoint of international agreements, though military men of experience and chemists the world over agree with the opinion of the United States Court of Appeals in the United States of America v. The Chemical Foundation, Incorporated, where it is stated that " even if no further advances are made by chemistry the next war will begin where the last left off "; in other words, the only way that we

can really abolish chemical warfare in future is to abolish war. The attitude of the civilized nations toward the question is much like that of a well known and often married actor toward matrimony. He explained his ninth wedding as a triumph of hope over experience.

At the time of the first gas attack, its terrible effect upon unprotected men naturally gave the war correspondents their opportunity and provided new copy for those engaged in creating bitterest possible sentiment against the enemy. Those first impressions created by the press have been lasting, and it is with greatest difficulty that the people at large can be brought to realize that chemical warfare is far from being the terribly inhumane agency that the pacifists have led them to believe. Statistics now available show that the deaths among American casualties from gas were only $\frac{1}{12}$ those from other weapons and the after results from crippling, disfiguring, and suffering infinitely less. The lay press would have us believe that whole cities, non-combatants as well as combatants, could be overwhelmed in short order with present known gases sprayed from airplanes; but there is nothing so far developed that gives grounds for such vivid pictures of the imagination. There is no reason to believe that the sufferings of gas victims are greater than those wounded by shell, and many have overlooked the fact that in the list of chemical reagents that have come to be classified under chemical warfare are many which are just as effective in causing temporary casualties without serious after effects and many which may actually be used for the saving of life.

Chloroacetophenone, for example, is a tear gas or lachrymator. It acts instantly even in small concentration and causes so copious a flow of tears as to render the subject quite unfit for military duty. After a few hours the effect passes off, leaving no after effects. Then there are the sneeze gases or sternutators, which, as the name implies, bring on continuous and almost violent fits of sneezing, which temporarily disable a soldier but again leave no detrimental after effect.

In addition there should be mentioned the safe, non-toxic screen smokes which will certainly be used with great effect should another national emergency arise. Such screens may be formed by titanium tetrachloride ejected under pressure from an airplane, by white phosphorus bombs or grenades thrown by hand or fired from rifles, and by smoke candles which give off dense clouds of thick black smoke. The proper use of such screening materials and many others of their kind will serve to blind the enemy by reducing visibility to zero, to obscure the number of troops, to render inactive battleships and land batteries, and to protect from annihilating fire many a body of soldiers.

After all, the greatest utility of the weapons of chemical warfare is in the element of surprise, in the possibility of combining various gases, smokes, and shell, and in the fact that gas will penetrate protected positions and drive out the enemy from hiding places which shell could never reach.

Through research the constants of war gases have been determined and their chemical nature used as the basis of research on means of defense. This has led to the present day gas mask for example. Representatives of most of the sciences, including psychology, have had a part in developing this defense equipment. The mask of to-day is indeed comfortable in comparison with the first models. It contains materials to filter out smoke, and in testing these, cigarette smoke has been used because it is believed to be in the finest state of subdivision. The cannister of the mask contains compartments filled with activated charcoal for absorption and with chemicals which by their definite reaction with the various substances change their character as the air bearing them passes through the cannister, leaving the exit mixture harmless.

The vesicants such as mustard gas, which, as is well known, bears no relation whatever to mustard, have made it necessary to devise protective clothing, a task more difficult than that of merely waterproofing fabric. Then there is the work for the physiological chemist, the pharmacologist, and others who must

determine what the chemical reaction of poison gases is when they reach the body. A full understanding of what takes place is the first requisite in designing methods of treatment. Some of the gases which, after all, are liquid or even solid at the time the shell explodes are absorbed by the skin, become hydrolyzed and set free in the body cell such materials as hydrochloric acid or perhaps arsenic. As these are quickly taken up by the blood stream, the effects may be serious or even fatal.

It will be seen, however, that while chemical warfare may be shown to be the most humane form of war, the most effective and at the same time the least costly, sight must not be lost of the fact that it is the only type of warfare which gives the intelligent man ample opportunity for self-defense. A sufficient knowledge of the various gases, smokes, and the like used enable intelligent men to devise efficient methods for self-protection, something which is impossible in the case of shot and shell.

Chemistry contributes another important item to the military establishment, namely, the flares, rockets, and pyrotechnic signals for use by day or by night. The star flares and great flares used to illuminate the battlefield and trenches were composed largely of the metallic element magnesium. One source of supply of this metal is the brine wells of Michigan and the method employed for gleaning the metal from its chloride is an electrolytic one not differing greatly in principle from the process by which aluminum is recovered from a solution of bauxite in cryolite. The magnesium in the star shells and flares is in the shape of a fine powder very similar to that one finds in flashlight powders. It is easy to see that the reduction of metallic magnesium to this powder is in itself a manufacturing operation involving fine technique. Then there must be colored lights, rockets that can be depended upon to release small flares attached to tiny parachutes, the number, arrangement, and color being part of a code, and colored smokes for use by day. Tracer bullets are also of great value, for being able to see the trajectory of a projectile is of great assistance in obtaining the proper range and aim, especially if the target is in motion.

Just as the automobile can be described in terms of the contributions which chemistry has made to its perfection, so also can both the heavier and the lighter-than-air craft be described. It is obvious that new alloys, or at least the new use of alloys, is involved in obtaining the utmost horsepower with light weight in airplane engines and that the lightest metals consistent with strength are needed not only in airplanes but particularly in dirigibles. Aluminum-magnesium-copper alloys have remarkable strength for their low specific gravity and so far have proved the best for this purpose.

Chemistry made an important contribution to the propellers of aircraft by providing an adhesive, waterproof, dependable, and strong, with which could be built up the laminated wood of the propeller. Then it was suggested how to cover these exactly proportioned and nicely balanced units, that they might be protected not only from changes in weight and dimension but also from the erosion caused by the rapidly passing air.

It is necessary to keep airplane wings taut regardless of temperature and moisture conditions. This is accomplished with airplane "dope," usually a nitrocellulose lacquer covered with a coat of flameproof cellulose acetate. The necessity of making large quantities of acetic anhydride for these dopes during the war led to the employment of fermentation processes which have since become commercially important for other uses. It will be obvious that the lubrication problems are intricate, that special types of chemically controlled fuels are demanded, especially in view of the fact that at high altitudes the scarcity of oxygen complicates the question of combustion. Combustion offers a further difficulty in dirigibles which carry great quantities of fuel. As this fuel is consumed, the ship becomes lighter, gas must be valved or allowed to escape to avoid reaching too high altitudes, and the possible radius of ship travel may thereby suffer. The problem became more acute in the employment of helium because of its higher cost. It led finally to the provision of condensers through which the exhaust gases from the motors pass and from which in con-

sequence water is recovered in quantity which more than counterbalances the weight of the fuel consumed.

While the question of balloon fabric is one of difficulty, what to put in the bag is of even greater importance. Hydrogen, the lightest of all gases, has the greatest lifting power and buoyancy, which greatly aids the maneuvering of modern dirigibles having gas capacities up to 5,000,000 cubic feet. Hydrogen is comparatively inexpensive. It cannot be purified for re-use; but its low cost makes that relatively unimportant. It may be replaced ten or fifteen times a year not because so much hydrogen escapes through the balloon fabric as that air diffuses through and so contaminates the gas as to make it unsatisfactory. The real difficulty with hydrogen is its highly inflammable and even explosive nature when mixed with certain proportions of air. The disasters in aviation due to hydrogen fires form a long list and a single incendiary bullet fired into an observation balloon has caused the death of those observers unable to take to their parachutes quickly enough.

In the scale of light gases, helium stands next to hydrogen. It is not as buoyant, does not have the same lifting power, and experts say that dirigibles filled with helium are more difficult to manage, respond less readily to the changes required in maneuvering, and call for an entirely different method of handling than do hydrogen-filled ships. But helium is absolutely non-inflammable and may even be diluted with a few per cent of hydrogen and still refuse to burn under any circumstances. The cost of helium alone really stood in the way of its utilization. Before the war, helium was a laboratory curiosity. Very little of it was to be found even in the museums. It had been discovered in the spectrum of the sun before it was known to be upon the earth. It was worth about $2,000 a cubic foot and the supply at that was very limited. Then scientists found that certain natural gas wells, particularly some in Texas and Oklahoma, contained appreciable amounts of helium and the chemists and engineers began research to learn how to win this helium in quantities sufficient

for military purposes. A scheme of gas liquefaction and separation by fractional distillation was adopted. Before long the price had tumbled from $2,000 per cubic foot to around $600 per thousand cubic feet. From that point on it has been a matter of constantly reduced costs until now helium has been produced at $60 a thousand with every prospect that $35, or even a lower figure, is attainable. Whereas hydrogen cannot be purified, helium can be and a plant for the purpose has been installed at Lakehurst to purify the helium used in the giant dirigibles of the navy. Another plant has been mounted on flat cars for the sake of proving that airships, however far from their home hangar, need not be embarrassed by lack of purification plants in various parts of the country. One of the great problems with helium continues to be an adequate supply for such a program as might be necessary in the event of an emergency; but with sufficient appropriations there is reason to believe that ample quantities can be found and separated from natural gas, leaving the gas as useful as originally for fuel and power purposes. A real difficulty is the storage of helium, for it permeates through all sorts of containers, including the densest steel. A number of schemes have been proposed for helium storage, some of them quite fanciful, such as the use of abandoned mines, concreted and otherwise lined for the purpose.

Remembering that war is a matter of resources, whatever may be said as to the importance of chemistry in all its relations becomes emphasized in the case of war. It becomes even more necessary to increase food supplies and carefully store any excess of supply from one harvest to the next. It becomes even more necessary to increase production, to eliminate seconds, to find domestic materials to replace those formerly imported, and to conduct industry generally at a high efficiency and at great pressure. What was done in the United States, during the World War, affords a good example. Potash had never been produced in America. It was very desirable, if not absolutely essential. One group investigated the possibility of potash from feldspar, another from the green sands, a third

from cement dust and blast furnaces, and still others from lucosite and alunite. The government and one of the powder companies chose kelp of the Pacific as a raw material and yet another began upon the Searles Lake brines. Potash was produced from cement dust by a method devised originally by Cottrell, a chemist. The Nebraska lakes yielded some potash while the prices were high enough to justify operations. Some was secured from the waste molasses of beet sugar factories, while the plant at Searles Lake, investing heavily in research, soon became the greatest factor and at present is the only plant continuing the production of American potash.

The jimson weed was found to be a source of atropine, in quantity attractive under the circumstances. Prospecting disclosed domestic supplies of tungsten, of chromium, and of manganese. Care was used in the use of tin for the weighting of silk and was recovered from the spent liquors. Under the stimulus of high prices, it became economical to recover many things from wastes not commercial in normal times. Chemical glassware and porcelain, long lists of reagent chemicals important to industry and science alike, and optical glass, all new to American manufacture, were soon provided and the quality raised until it exceeded that of goods previously imported. Synthetic organic chemistry was called upon to do in five or six years what those specialists in other countries had done in a generation. There had to be antiseptics, anæsthetics, sedatives, and germicides in unprecedented quantities and of the newest synthetic types. Even industries which never before had considered chemistry of any interest to them began to see in it great potentialities for service when the customary sources of raw materials failed, when specifications were so written as to require a degree of perfection only possible under scientific control, and when manufacturing economies attainable only with the help of the scientist became desirable. Chemistry works just as effectively in peace as in war; but its relation to national defense in the few instances herein outlined and in many, many more which have not been mentioned merely serves to emphasize its importance as a fundamental science.

Chapter XIV

CHEMISTRY A TOOL

Tools are so commonplace that they are taken as a matter of course and thought is seldom given to what the consequences might be if we should suddenly lose all these mechanical devices with which many of the forces of nature have been overcome and materials largely fashioned to suit our own requirements. Yet frequently some bit of work must be left unfinished until a particular tool can be found to meet the requirement. As our mechanical contrivances have multiplied, the manufacture of tools themselves has grown to be a great industry and special tools for a particular mechanism form a part of the initial equipment.

By reference to such remnants of ancient civilization as are left to us, we know that the race must have made its way for a very long time without tools of any kind, and that by and by sharpened sticks and stones began to be used, though their application was obviously extremely limited. The man who was first to discover metal and to learn how to fashion it into a serviceable tool or weapon had a tremendous advantage over his companions both in peace and in war. This invention was doubtless preceded by the discovery of fire, and though first used to satisfy the craving of men for light, it could not have been long before the benefits to be derived from the control of heat must have been recognized. One can well imagine the consternation which came with the first acquaintance with fire. And to have found something which would withstand all but the hottest flames must in itself have brought joy, even before its use as a tool had been conceived.

We are told that glass was first dicovered in the ashes of a fire upon sands where sufficient alkali happened to be present to make possible the fusion of the sand into a rough sort of

glass. We do not know how long it may have been from the time chance led to the discovery of metals and glass until ways were devised for producing quantities which would enable something to be fashioned from the material.

We are most impatient to-day in awaiting discoveries which result from the continuous research of organized science. And as we shall see later, development in several directions is arrested until new theories can be evolved and facts ascertained to test them. Yet it is almost inconceivable how slowly civilization developed during that long time when everything depended upon chance discoveries. The same phenomenon which to-day is a well known chemical reaction must have been demonstrated by nature innumerable times before some one caught the idea and began to develop the truth from what he had observed. Real advance began when men applied the scientific method to their problems. By some simple systems of observation and records, such natural materials as were suitable for particular uses could be selected, and as the record was passed from mouth to mouth and from generation to generation, there began to be accumulated experience which indicated the particular materials and their best use to accomplish given ends. This sort of thing is now done in a fraction of the time with the elimination of uncertainty and with amazing economic results.

By and by the time came when natural materials were unsatisfactory and changes in them were sought so that specifications might be met. It is only a comparatively short time ago that the erection of a lighthouse at Eddystone, England, made necessary the preparation of new materials which would be more satisfactory in service than those from which previous houses had been built. To meet this need investigations which led to the discovery of material now known as Portland cement were undertaken. This is but a single illustration of what has been going on for hundreds of years in many directions.

This round of first using things as found in nature and then changing them better to serve the purpose continued until

within a generation or two with nothing to change the direction of the work. Meanwhile theoretical science and search with no other purpose than the establishment of truths had led to such conceptions of the formation of matter that chemists began to wonder if it were not within the realms of possibility to take some of the simpler materials of nature and from them build up compounds the like of which had never been found on the earth. This synthesis has marked the rapid advance of chemistry in the Twentieth Century. But with it there has come a still better understanding of the profound laws upon which matter itself is constructed.

The natural materials which compose the earth are few in number, and the ancients considered them relatively simple. They believed that but four elements composed the universe, these being earth, air, fire, and water. Gradually the philosophers began to note differences in properties which made a more strict classification possible, and a slow advance began accompanied by a great deal of argument and much useless experimentation.

After a time a new cult sprang up, the members of which made the study of the basic materials their life work. The changes which they were able to produce in their laboratories impressed them with the possibility of changing one material into another, although it is the belief of some that this transmutation of the metals in particular was merely symbolic of the salvation of the spirit and that in consequence alchemy, as the study was called, was in reality a variety of mysticism. In any event, the alchemists in their effort to transform the baser metals into gold and to discover a compound which would be the elixir of life, chose to clothe their work and records in the most elaborate secrecy. Their written records are filled with abbreviations, symbols, formulas, and diagrams having for their purpose to mystify and conceal rather than to impart knowledge. Hence the designation "alchemy" which may very likely have been derived from the Arabic and mean "to hide," "al" meaning "the" and "chema" "to hide." Indeed some of the writings of the alchemists more nearly approach secret code than

anything else. Many symbols are found for the same material, even in the writings of the same observer. And where reactions between substances were little understood, a great flow of words and phrases was employed to conceal the fact. To be sure, this habit of substituting verbosity for real information is not confined to the age of alchemy.

Since that time a great range has been covered. Through laborious research over centuries, but mostly in the last two hundred years, chemists and physicists have been able to isolate and identify some ninety elements and in addition several other compounds which, when discovered, were thought to be elements but which later investigation has shown were really modified forms of previously identified elements. According to modern theory only two remain to be discovered. By an element the chemist means a fundamental substance which cannot be resolved into a simpler form of matter. In the table of elements will be found many common substances such as iron, copper, gold, silver, and other metals, alkalies, and gases, as well as many strange names which for the most part represent substances that are rare and not used to an extent to make them familiar. These elements enter into compounds, some of which are very numerous. But while there are ninety-two elements, a dozen of them form 99 per cent of what we know of the earth's crust. These with the percentages are as follows:

Oxygen	49.85	Potassium	2.33
Silicon	26.03	Magnesium	2.11
Aluminum	7.28	Hydrogen	0.97
Iron	4.12	Titanium	0.41
Calcium	3.18	Chlorine	0.20
Sodium	2.33	Carbon	0.19

How long this number will remain intact is a question, for already there are many who believe that all matter is a manifestation of two forms of energy, electrons and protons. Work with hydrogen, helium, uranium, radium, lead, etc., indicates that there is a gradual transition of some of the more complex forms of matter into the simpler forms. Some research has led

observers to believe that such a substance as tungsten can be reduced at once to helium by a powerful explosion which causes the disintegration of the more complex molecule into the simpler one. Complete demonstration of this transition remains to be made.

While this is to some extent a realization of the dreams of the alchemists, it has quite a different object in view and consists more in breaking down complex elements into simpler forms than the conversion of base metals into more desirable ones. And while the modern chemist seeks no elixir possessing supernatural powers, he accomplishes wonders in safeguarding and extending the span of life, which certainly would have caused any alchemist to have cried "Eureka!"

Contrasted with the alchemists' desire to conceal, the modern chemist is more than anxious to have the nontechnical audience fully sympathize with his efforts and understand as much as he will of the aims of his work, in order that his research may have full appreciation and support. He strives to make clear his nomenclature, his symbols, his formulas. He endeavors to add human interest by reference to the human body itself which is a veritable collection of laboratories carrying out chemical reactions and processes.

In a delightful little pamphlet entitled "Treasure Hunting of Today," Doctor Robert E. Rose makes the following statement:

"Draw a breath. You have inhaled 3,000,000,000,000,000,000,000 little particles of air, a jostling, pushing crowd of oxygen and nitrogen particles so crowded that each one bumps his neighbors and is bumped back five billion times every second, each trying to rush 1,500 feet in that time. Exhale, and out rush an equal number of molecules, but 120,000,000,000,000,000,000,000 oxygen particles that went in do not come out, while their places are taken by carbon dioxide and water that came out of your body. Weigh the crowd coming out and it will be found heavier than that which went in. You are losing weight with every breath. Drink a glass of water and you have swallowed 1,865,000,000,000,000,000,000,000,000 molecules of water.

Somehow, out of all the myriads of molecules that you eat and breathe, you get yourself made and keep your body running.

"All matter is composed of such trifling particles. A ton of steel is made up of fragments so minute that a thousand million million are needed to form the point of a needle. But each kind of matter, if different under like conditions, is composed of different molecule units. Units of water, units of iron, of sugar, of salt, of diamond, of sulfur. Small as these molecules are they are usually not simple but are composed of simpler particles, the atoms. Can you imagine the physicist and chemist pulling matter to pieces, nearly hopeless at the complexity, but still hoping to reach an understanding?

"Millions of different kinds of substances, millions of different kinds of molecules, and, if these are complex, then tens of millions of different atoms. That was to be expected; but in reality it was found that there are only some 80 different kinds of atoms, and that a fourth of that many form the great majority of molecules. Moreover, rarely are there more than three or four different kinds of atoms in any one kind of molecule."

It is with such infinitesimal particles that the scientist works in his effort to change the form and properties of matter to meet diverse needs. In his effort to reduce his problems to the simplest terms, he strives to identify the actual kinds of materials composing the earth, the sea, and the atmosphere. This has led to new words, terms, and phrases, new methods of expression, indeed almost a new language. In this discussion the reader will not be confused by the use of this technical language, but it may be well to illustrate one or two of the ordinary chemical expressions and explain something of their relations.

There are relatively few elements as we have seen, but there are almost countless compounds made by the combination of these elements. For example 150,000 organic compounds have been listed while billions are theoretically possible. There is no better simile than to compare the elements with the letters in our alphabet, and the compounds with the words which are possible by the various arrangement of the individual letters of

the alphabet. Now if that infinitesimal portion of an element which is called an atom be represented by a letter, then the molecule, which is the smallest subdivision of a compound of two or more elements possessing all of the physical and chemical properties of the compound, may be compared with the word. It will be seen from this that an inordinate amount of work might easily be required to resolve a molecule into its component parts. But scientific methods have made this possible. The chemist now wants to know not only of what atoms or elements the molecule or compound is composed, but he must know how they have been put together. Of this he has already learned much, and as stated earlier, has so perfected his technique and has acquired such great experience and knowledge that in many instances he is quite able to cause atoms to become attached to molecules at points which will best serve his purpose and yield a new molecule with a new set of properties. It is not so simple as the addition of a letter or two to a word to form a new word with a new meaning, and when one considers that in all this work the chemist manipulates particles so small as to be beyond the reach of even scientific instruments, the vastness of the problem is somewhat understood.

From this it will be seen that the modern scientific method is first to learn by thorough examination and research to what a natural product owes its utility in the hands of man. Nearly everything that is used in the science and art to-day is found in the impure state. Thus, iron appears as an oxide of iron or some other ore in which the metal is combined with other chemical elements in a form which must be changed before metallic or pig iron is available. Naturally the next step to be taken after thorough familiarity with the properties of the substance is its purification. In this process interfering substances are eliminated and the full benefit of the pure element or compound obtained. It often happens that the desired material is difficult to obtain even in the raw state. The purification may be tedious, costly, or even hazardous. And for one reason or another it becomes desirable to manufacture the material in the laboratory. This has been possible with a number of substances.

INTERNATIONAL TABLE OF THE CHEMICAL ELEMENTS AND THEIR SYMBOLS

	Symbol		*Symbol*
Actinium	Ac	Neodymium	Nd
Aluminum	Al	Neon	Ne
Antimony	Sb	Nickel	Ni
Argon	A	Niobium	Nb
Arsenic	As	Niton	Nt
Barium	Ba	Nitrogen	N
Beryllium	Be	Osmium	Os
Bismuth	Bi	Oxygen	O
Boron	B	Palladium	Pd
Bromine	Br	Phosphorus	P
Cadmium	Cd	Platinum	Pt
Calcium	Ca	Polonium	Po
Carbon	C	Potassium	K
Cerium	Ce	Praseodymium	Pr
Cesium	Cs	Radium	Ra
Chlorine	Cl	Radon	Rn
Chromium	Cr	Rhenium	Re
Cobalt	Co	Rhodium	Rh
Copper	Cu	Rubidium	Rb
Dysprosium	Dy	Ruthenium	Ru
Erbium	Er	Samarium	Sm
Europium	Eu	Scandium	Sc
Fluorine	F	Selenium	Se
Gadolinium	Gd	Silicon	Si
Gallium	Ga	Silver	Ag
Germanium	Ge	Sodium	Na
Gold	Au	Strontium	Sr
Helium	He	Sulfur	S
Holmium	Ho	Tantalum	Ta
Hydrogen	H	Tellurium	Te
Hafnium	Hf	Terbium	Tb
Illinium	Il	Thallium	Tl
Indium	In	Thorium	Th
Iodine	I	Thulium	Tm
Iridium	Ir	Tin	Sn
Iron	Fe	Titanium	Ti
Krypton	Kr	Tungsten	W
Lanthanum	La	Uranium	U
Lead	Pb	Uranium X	
Lithium	Li	Vanadium	V
Lutecium	Lu	Xenon	Xe
Magnesium	Mg	Ytterbium	Yb
Manganese	Mn	Yttrium	Y
Masurium	Ma	Zinc	Zn
Mercury	Hg	Zirconium	Zr
Molybdenum	Mo		

The chemical symbols used to write formulas are nothing more or less than a sort of chemical shorthand. They are terrifying to the layman because he has no acquaintance with the substances for which they stand, let alone these abbreviations for their names. In the accompanying table of the elements, the symbols are given and it will be seen that generally the initial of the name expressed either in English, Latin, or some other language is the symbol for the element. A second letter is combined to avoid confusion where two or more elements have names with the same initial. In the use of these symbols to write formulas the chemist uses parentheses to indicate that certain combinations are not broken down in such reactions as take place, and he uses subnumerals to indicate the proportion of the element within the compound. Indices and various characters are used to convey other information. It is not necessary for the nontechnical reader to familiarize himself with this system of symbols and formulas, but to remember only that to the chemist they mean something very definite, that there is nothing of mysticism or a desire to conceal information about them, and that if he is interested it is a comparatively simple matter to master this sign language.

The names of chemical substances have not been devised to confuse the reader. They do seem unnecessarily long at times, and chemists have even been accused of competing to see who could devise a word containing the greatest number of letters. A chemical name indicates exactly what the substance is. It frequently indicates its origin, the method by which the compound has been made, and from this in turn the chemist may be able to know some of its characteristics, or to predict its behavior. For many of these compounds no shorter names have been proposed or are necessary, but the public has been quick to devise its own abbreviations for those substances that have come to mean something to it. Every one knows TNT, but comparatively few know that these letters stand for trinitrotoluol. We often hear some one inquire for a package of "hypo,"

but the customer rarely knows that sodium thiosulfate is the material he means.

It will be obvious that if chemistry concerned itself with the properties of the substances forming the earth's crust, and that if chemists in coöperation with workers in other scientific fields undertook to change natural substances to make them more suitable for the needs of men, and if they go further and construct new materials to meet new specifications, everywhere we go we must expect to find some indication of the chemist's work.

H. N. Casson, in order to emphasize our dependence upon the contributions of chemistry, wrote the following:

"'What does chemistry mean to me' said Mr. Narrowhead as he looked at this page, printed with ink made by a chemical process, on paper made by a chemical process.

"As he pushed back his cuff, bleached by a chemical process, and laced his shoes made of leather tanned by a chemical process, he glanced through a pane of glass, made by a chemical process, and saw a baker's cart full of bread, leavened by a chemical process, and a draper's wagon delivering a parcel of silk, made by a chemical process.

"He pulled out his pencil, made by a chemical process, and wrote a reminder in his notebook bound by imitation morocco, made by a chemical process.

"Then he put on his hat, dyed by a chemical process, and stepped out upon the pavement of asphalt, compounded by a chemical process, bought a daily paper with a penny refined by a chemical process and proceeded to the office where he dealt in a certain chemical compound called coal.

"'No,' he added, 'of course not, chemistry has nothing to do with me.'"

We shall now proceed to consider briefly the way chemists set to work to make some of its contributions in a few fields in which the race has attained results which may almost be described as superhuman.

Chapter XV

ANALYSIS AND SYNTHESIS

To the majority, science impresses itself only by means of its tangible results. We want more to enjoy and to utilize. We like the fruits of science to be presented in the form of things we can see, eat, smell, feel, or hear. The popular attitude is that radio, for example, is an achievement to be enjoyed and never mind how much or what kind of research and experimental work necessarily preceded it. Motion pictures entertain or instruct without more than a very few in the audience feeling any appreciation for the work that has made them possible or any obligation to the scientific workers who have devoted their careers to its development. Now all scientific work is based on a more or less complete knowledge of the characteristics of the materials found in nature, the ways of stuff. This knowledge is won through the most painstaking analysis, experiment, and synthesis.

Analysis is the process by which compounds are separated into their components usually expressed as elements; but very often the results in analysis may be interpreted in terms of compounds. This must be based on a pretty complete knowledge of how the compound could be formed or made and the tendency of certain elements to combine one with another. For example, an analysis of water may show present certain quantities of chlorides and sulfates, also sodium, calcium, magnesium, etc. These are reported separately; but it is customary to indicate also the probable amount of the bases combined with the requisite chloride and sulfate to produce the salts of the alkalies. There are some ninety-two elements catalogued by the chemists as those composing the earth's crust, the water, and the atmosphere. Four have been added very recently, two, in fact, dur-

ing 1925, one in 1926, and the theorists tell us that there are probably two yet to be identified. With so many components it is obvious that the possible combinations in varying amounts are literally limitless. Some look upon analysis, the first step in our work, as routine uninteresting work to which they attach little importance, and yet careful analysis underlies all scientific achievement.

Several important discoveries have waited until greater refinements have been achieved in analytical chemistry, just as discoveries frequently await the production of finer instruments and tools with which to work. As now employed, analysis is based on the chemical and physical properties of the elements and their compounds, these being constant under reproducible conditions. Among others may be mentioned solubility, color, boiling points, melting points, electrical conductivity, odor, crystal structure, spectrum emission, polarity, specific gravity, and X-ray patterns. Even a partial list of these constants provided 2500 pages of closely printed material in International Critical Tables of Physical and Chemical Constants. Such work is never completed, for new things are constantly being added to the old lists.

The difference between some materials is exceedingly small, as, for example, the point in the molecule at which a significant atom is attached. Sometimes there is only a one-atom difference in two materials which are totally different otherwise. Mercuric chloride and mercurous chloride have a difference of one atom of chlorine, but the one is a violent poison and the other a reagent in medicine. It will be obvious, therefore, that analytical chemistry is a science requiring the most exact measurements, refined technique, and a close adherence to laboratory procedure. Lawsuits of some magnitude have depended upon methods of analysis, and the failure of two groups of men to follow the same analytical procedure in every detail has been the basis of many a prolonged controversy.

Solubility is a property which is very helpful in analysis. It is influenced by temperature, as well as the solvents, of which

water is the most important, followed closely by alcohol and solutions of the acids and the alkalies. Then there are organic solvents derived from petroleum and coal tar, and solutions of chemicals in some one of these solvents are also used as reagents. The difference in solubility, then, affords one method of separating materials in analysis, and guided by this knowledge the same method is frequently used in manufacture. We have an instance in artificial silk where the filament is brought into a bath in which it is insoluble, whereupon it immediately precipitates out in the form of the thread.

In many industries, quantitative separations are obtained merely by changing the character of the solution. Thus, if one had paraffin in a solution of benzol, water might be added to the solution and a point soon reached where the benzol diluted with the water will be rendered incapable of holding the paraffin in solution. Some substances are insoluble, carbon being a typical example. At the time when there was some difficulty regarding black dye for hosiery, a gentleman entered the office of a consultant, carefully closed the doors and windows and, after being further assured that no one could overhear the conversation, announced his great idea. Having observed that carbon is the blackest of all things, this man sought to solve the dye problem by impregnating the textile fibers with a solution of carbon. When asked how he expected to do this, he disclosed that he had come to the consultant for the purpose of learning how to dissolve the carbon. There are some substances so readily soluble that they are merely listed as such, while others dissolve to the extent of more than nine hundred parts by weight in cold water. Still others are so soluble that they dissolve in the moisture which they absorb from the air and consequently are seldom seen in the crystalline state.

Color is another distinguishing characteristic, and chemical compounds offer the entire range of shades and hues. You need but be reminded that all dyes are chemical compounds. The importance of color as a constant for analysis is not confined to the material itself. Its compounds and their solutions, which

usually have a different shade or color from the material itself, tell the story. The fusions of compounds give characteristic colors, as do their flames when they are burned in certain combinations, as with borax. Others give off gases characteristically colored. The change of color when heated with a reducing or with an oxidizing flame is made the basis of the blowpipe analysis extensively employed in mineralogy where the sample may be held on a bit of charcoal and have played upon it with a blowpipe either the reducing or the oxidizing portion of the flame from a Bunsen burner or other source. The reducing flame takes oxygen from the material under analysis while the oxidizing flame has the opposite effect as its name indicates. The wide-spread occurrence of such materials as sodium, well known as sodium chloride or common salt, sodium carbonate or washing soda, which gives an intensely yellow flame when burned, makes it impossible accurately to identify with the unaided eye all the substances in the compound by the color of its flame. Therefore, color screens are sometimes used. Cobalt glass, for example, absorbs the yellow, but allows one to see the presence of potassium in the flame.

A far more accurate method, therefore, is the spectrum of the flame of the salt. The lines which appear in the field of the spectroscope when a luminous flame is studied have been carefully mapped, measured, and numbered, and spectroscopy has become an exact science. Lines of the flame of an unknown can be compared with standard spectra and elements identified with precision. One of our elements, helium, was first observed in the sun's spectrum, and it was several years before this element was found on the earth. It will be recalled that it is the spectroscope that permits an analysis of the stars. The story is told that a group of scientists were discussing the impossible and decided that of all things the analysis of the stars was the most impossible. This seemed a reasonable conclusion, since there is no way of bringing the star or an unaltered part of it into the laboratory. It was not long after that spectroscopy was developed to the point where it could be

used in conjunction with the telescope, and now stars may be analyzed.

The boiling and melting points are also characteristic. Here again is emphasized the importance of small differences, but these points are so constant that they are frequently used in commercial specifications. The conditions under which the determinations ought to be made and the apparatus to be used are carefully specified. The research worker obtaining an unknown compound, as the result of his experiments, endeavors accurately to determine the melting point and boiling point, as well as the specific gravity, as the first step in identification. All materials do not have a sharp melting or boiling point. They may decompose upon heating or exhibit other phenomena that make accurate measurements of this sort impossible.

Electrical conductivity is another characteristic applicable usually to metals or salts in solution. The electrical conductivity of water, for example, is a measure of its absolute purity. The crystallography of the chemical elements and compounds is another means of identification and offers the key to microanalysis, a new development in which minute quantities of unknown materials are analyzed under the microscope. Here the form of crystals, their color, and their chemical reactions in the presence of minute quantities of reagents tell the story. Not only has it been found that smaller quantities of unknowns are required, as well as smaller quantities of reagents and other equipment, but that time can be saved. The net result in one control laboratory is an annual saving of some $20,000 as compared with the older macroanalysis.

Odors and tastes often guide the analyst; indeed, the tendency at once to taste and smell unknown materials introduces a certain element of danger, for many compounds are exceedingly unpleasant if not indeed poisonous. In some commercial products it has become the practice to add some highly fragrant volatile oil to cover up the characteristic odors of other materials, which, unless so cloaked, would immediately betray their presence to the cautious buyer. A practical use

of this difference in odors is one method for distinguishing between natural and artificial silk. When burned, natural silk gives off the odor of burning animal matter like burning feathers, while artificial silk has a fragrance of its own which cannot be confused with the other.

The optical properties of compounds is still another characteristic. The ability to change the plane of polarized light may be cited as an example. If light is passed through a Nicol prism, that which emerges will be found to vibrate in a single plane. If this is now passed through a solution of the material under examination, it may be turned to the right or left, depending upon the optical activity of the substance. By using another prism attached to a graduated scale, the angle through which the plane of light has been turned may be measured. The optical activity may therefore be reported in so many degrees or if, as is the case in the examination of sugar, international standards have been set for the concentration of the solution and the temperature at which the work is to be done, the scale may be graduated in per cent. If the plane of light is turned to the right, the material is known as dextro rotary, and if to the left, lævo rotary.

One of the newest tools in the hands of the analyst is the X-ray. Investigators have found that photographs made under specified conditions give characteristic lines which may be interpreted in terms of patterns known as the X-ray patterns of crystals. These patterns are due to the arrangement of atoms in exact planes in the molecules and give us the key to the structure of crystals, a subject of intense interest not only for its theoretical, but for its practical value as well. Thus, it has been found that two carbons, identical so far as ordinary chemical and physical analysis are concerned, do show a difference in X-ray patterns and that one of these is more satisfactory than the other for certain industrial applications. The same is true of certain metals and alloys, and this method of attack has been particularly useful in detecting minute traces of impurities in metals.

Having determined the nature of the elements present, the analyst proceeds to learn their proportions. He goes from qualitative to quantitative analysis. Here he uses a number of methods based upon qualitative analysis and may employ volumetric or gravimetric analysis. Differences in electric potential, and whatever small difference in constants may aid, should influence quantitative separations. He employs organic salts or dyes as indicators. These are extremely sensitive to acid and alkali, and form the basis of a system of acidimetry and alkalimetry which is important. The indicators themselves are classified according to their sensitiveness, and where, because of other substances, the exact end point, where a color change occurs, may be obscured, the potentiometer may be employed with great satisfaction and increased accuracy.

Quantitative analysis requires special sorts of glassware which will withstand sudden and extreme changes of temperature and at the same time remain insoluble to the mixtures they must contain. Filter papers for the separation of solids and liquids are required and these are frequently of cellulose so pure that their ash is practically negligible. For much of the work platinum must be employed or, perhaps, fused quartz. Porcelain, capable of being heated almost to a white heat, is essential, and as a result of the war emergency the glass, the filter paper, and the porcelain, without which essential chemical control work in industry, analysis in medicine, and the prosecution of research could not go forward, were satisfactorily developed in the United States. There are a host of other requirements — heat resisting alloys, constant temperature baths and furnaces, devices of rubber and of wood — all hedged about with specifications so exacting that he who undertakes to supply it to laboratories on a commercial basis does so with the knowledge that it can never be a source of great fortune.

Since volumes are so important, devices which deliver liquids in tenths and twentieths of a cubic milliliter must be graduated; allowance must be made for temperature and for the adherence of the liquid to the sides of the vessel. It is indeed work calling

for the utmost precision. The analytical balances are as carefully made as the finest watch, and in the case of the assayer's balance may have a sensitivity of .01 of a milligram. The fractional weights are bits of platinum and the larger sizes are plated with gold or platinum, that corrosion may not destroy their accuracy.

The metric system is used in this scientific work, since it enables more accurate measurements to be made and facilitates their expression. The microscope is supplied with a filar micrometer, a device by which the finest line can be made to traverse the field of view and with a vernier read for the size of infinitesimal objects. The interferometer finds employment in the measurement of light. Thermostats are developed which will maintain a water bath or an oven for hours or days at a time at a predetermined temperature within .01 of a degree. Long trains of intricate glass apparatus are fused together, glass especially for this purpose being provided, thanks to chemical control. Even the motion picture is brought into play in the study of crystal formation and the studies of the differences which occur in crystal structure in metals as they become fatigued by alternately applied stresses.

Even the most exact analysis, while telling of what a material is composed, cannot indicate how it was brought together. Many a small boy, for example, has demonstrated of what a watch or clock is made, but has not been able to reassemble the parts. There are many variables — time, temperature, concentration, the order in which things are assembled — all make a mighty difference in chemistry. These facts are sometimes overlooked by the clients of consulting chemists who cannot understand why the charge for duplicating a particular substance may be hundreds of times that for its mere analysis. A cook who specializes in a given thing, let us say a cake, may tell others exactly what she uses and how she uses it, and yet none of her pupils can really duplicate her product. Working out the "know how" is one of the great difficulties in duplicating materials.

Synthesis, the putting together of things, naturally follows analysis. It is a most difficult subject, for, notwithstanding the cumulative knowledge of the past two hundred years, we do not yet know enough of the constitution of matter and the ways of things to make synthesis easy. That which has been accomplished is greatly to the credit of chemistry; but it must be remembered that the chemist is, after all, working with things he never sees. He is concerned in synthesis with altering, combining, and fashioning atoms and molecules so small that they have never been seen. To emphasize this, Doctor W. R. Whitney, in his Los Angeles address before the American Chemical Society, said that if all the electrons, now believed to be the ultimate particles of matter, in a drop of water could be enlarged until each of them became as big as the original drop of water they would form a layer three feet deep entirely covering the earth. The molecules are so small that if a glass of water were thoroughly stirred with all the water in the earth and in the sea, and a second glass filled with a mixture, it would contain two thousand of the original molecules.

The first notable synthesis was that by Wöhler early in the nineteenth century. This is a classic in the science, since it indicated the absence of a sharp line of demarcation between organic and inorganic chemistry. He made urea, normally found in the excreta of animals, from substances of inorganic origin. In modern times we are very likely to think of Perkin's work as the beginning of synthesis, for in a search for artificial quinine he produced the first of the coal tar dyes, mauve. Since then, the number of synthetic compounds has increased at a wonderful rate. The products of plants such as indigo, camphor, and rubber have been synthesized. Resins are made in the laboratory and coal tar, the starting point in so many of these syntheses, has yielded vanillin, the active principle of the favorite flavor, vanilla. Acetic acid, once derived solely from the destructive distillation of wood, is now made synthetically from acetylene gas, derived from carbide, in turn made from coal and limestone. We reach into the gases of the air, com-

bining hydrogen and nitrogen to form ammonia, itself the starting point in the production of synthetic nitrogen compounds.

With an increase in our knowledge of catalysts, still greater things are promised. A catalyst is a material which by its mere presence promotes a reaction without itself suffering change or being present in the final product. Mere traces of a catalytic body may suffice and its physical condition is believed to be more important than its chemical composition. Not only are there positive catalysts which accelerate reactions, but there are negative catalysts which retard action. Among the industrial successes may already be listed the catalytic process for the manufacture of sulfuric acid, methods for the hydrogenation and purification of animal and vegetable oils, the fixation of atmospheric nitrogen, the oxidation of ammonia, the manufacture of the acetic acid group from acetylene, synthetic methanol and butanol, and types of motor fuels. Another important phenomenon in synthesis is the action of light, the work with which is known as photosynthesis. Baly, of Liverpool, has succeeded in obtaining a glucose-like sugar by the action of ultra-violet light on formaldehyde. He also hopes to synthesize a protein with the use of ultra-violet light.

Electrical energy is also employed to great advantage in obtaining high temperatures without the disadvantage of residues left when other forms of energy, such as from coal, are utilized. Artificial abrasives are made from sand and alumina, artificial graphite from coal, and even gems have been produced synthetically in apparatus employing high temperatures and pressures. The active principles in animal excretions such as adrenalin and thyroxylin have been produced synthetically.

As our knowledge increases we believe that in time molecules may be built to order. Should this become a possibility, it may be expected to have a profound influence not only upon industry, but upon the health of the world. What has been done in perfecting compounds which enable poisonous materials to be introduced into the delicately balanced organism of the human body to destroy invading diseases without detriment to the host

gives ample reason to expect ultimately such an accomplishment.

The customary order of procedure, then, is analysis to learn with what we have to deal, then the improvement of naturally occurring compounds by their purification or separation from things not wanted. Finally, synthesis in the laboratory, producing materials which are homogeneous and constant in quality, being thereby better suited to man's needs than those compounds nature provides. The climax comes in the construction of molecules not found in nature and designed with special reference to the wants of the race as they have developed through the ages.

Chapter XVI

THE TREND AND PURPOSE OF MODERN RESEARCH[1]

All ages have their fads and fancies, in science as well as in fashions, and although science shifts its emphasis slowly and without regularity, nevertheless, we find one theory after another holding the center of the stage. With the development or unfolding of science from the days when the composition of the earth and its envelope was expressed in terms of four elements, down through the discovery of our modern atomic list, to the present time, when many hold all matter to be ultimately one or two forms of energy, there has come about an almost incomprehensible diversity of theories and of research activities. The chemist may still be fairly said to seek elixirs of life and the transmutation of metals, but unlike the alchemist, who had these as his only object, the chemist touches our modern life at so many points as to require him to specialize within more and more narrow limits. However, he has not reached the point where he must confine himself to so special an interest as the medical graduate who told his friend that he would specialize on the ear, but he had not decided whether it should be the right or the left ear.

It will be useful to consider a few guide posts in modern research and to summarize some of the points stressed elsewhere in this volume. If modern chemistry as represented by all its specialists is united upon any one problem, it is that all-important one of the ultimate constitution of matter. Little by little some of the complex substances of nature have been taken apart, but we have not yet completely torn down the structure to its unit building blocks, and until we do we cannot

[1] Presented in part at the Stated Meeting of the Franklin Institute, November 19, 1924.

reassemble these blocks in a structure more to our liking, nor can we know how to fit blocks of all sizes, shapes, and colors into our building plan. We have been following a stream to its source and have mapped out several branches, each a subdivision of its predecessor, but we have not yet come to those damp patches of earth which are the real source. Until then, we cannot expect to direct the stream effectively in a predetermined direction to serve our needs.

To many it seems that the ordinary work of chemistry has been accomplished. So many compounds have been taken apart and put together again that we should have accumulated the necessary preliminary training and experience to prepare for the early discovery of really great things. The progress report that can be made on the effort to separate a single molecule from the large crowd and so study its mechanism and behavior is encouraging. Modern conceptions of atomic structure not only serve to explain many of the phenomena uncovered through present-day research, but also emphasize the difficulty of the problem. Thus we are informed that, should we succeed in devising apparatus to enable the hydrogen or the helium atom to be seen, we could not see it, for it travels at too great a speed. The work of such men as Bohr, Lewis, and Langmuir has succeeded in establishing many facts relative to organic, inorganic, molecular, and atomic structure. The Braggs, father and son, Wyckoff, Hull, Davy, and the group utilizing the X-ray have already established many facts regarding space structure, and this work has progressed to the point where it has a practical application in carbon manufacture and in metallurgy. The methods for studying the electron as devised by Millikan and others are indicative of the marvellous technique characterizing our research to-day, making possible actual observations and experiments by which to prove our latest electronic theories.

To those who fail to keep pace with the day-by-day work, accounts of such achievements come as revelations indeed. Shortly after becoming a graduate student, circumstances led a

man into industrial work at a point quite removed from scientific influences. As a student, no one had endeavored to impress him with the value of membership in scientific societies, nor had journals been recommended as important equipment in pursuing his chosen work. Of course, he soon lost contact with what research was doing, and he never forgot his reaction toward an instructor who came from a university some three years later to give a high school commencement address. The ease with which he discarded the atom as the ultimate unit of matter was a shock and at the time gave him the impression that the lecturer was merely trying to overwhelm the townspeople.

Experimental work with the infinitely small, which to-day is in progress in nearly every laboratory, gives us ample reason to believe in eventual success for those who are intent upon unravelling nature's innermost secrets. Having established many truths with respect to atomic and molecular structures, many leading minds are working upon the problems incident to surface phenomena, catalysis, and oriented structures as possible explanations for the erection of enormously complex structures from the simplest materials. Just as the dividing line between organic and inorganic materials has grown less and less distinct, so also may we soon have difficulty in distinguishing between crystal and colloidal structure, and may find the space lattice with which crystal structure is being determined also applicable to colloids.

Our day is unique in the extent to which scientists are cultivating the borderland between the major divisions of science. Excellent and well known examples are to be found in geophysics, astrophysics, and biophysics. Physical chemistry, developed rapidly as a specialty, has grown in importance until it bids fair to dominate the entire chemical field. Its laws and theories are being everywhere applied. Methods peculiar to physical chemistry find a place in all research laboratories, and many of our most remarkable recent achievements in industry must be credited to men well grounded in its principles. Bio-

chemistry affords opportunities unsurpassed by any science and worthy of any genius, dealing as it does with the most complex substances; the problem is further complicated in that reactions must be interpreted almost in terms of life itself. Here, too, the infinitely little is the important thing; and while one group concerns itself with the isolation and identification of these elusive bodies, another addresses its attention to the far-reaching problem of the relation to life of these unseen factors. Enough has been demonstrated, for example, regarding the place in nutrition of those food accessory substances called vitamins, to make it desirable to know whether foods believed to be devoid of them can be endowed with the potentialities of foods known to have the properties so profoundly influencing body growth, repair, and maintenance. Until recently it has been thought that this could be done only by isolating the vitamin in question and then preparing it in concentrated form for addition to such materials as milk reconstituted from dry skim milk and neutral cocoanut fat. Once isolated, there is the possibility of synthesis, followed by commercial production at favorable costs. Now comes the interesting report that fats such as cottonseed oil may be made to take on the virtues of vitamin-A-bearing fats, such as cod-liver oil, by exposure to ultra-violet light. Perhaps we shall find that, after all, vitamins are not chemical compounds, but forms of energy, and that they fit into the modern theories of atomic structure.

Concurrently, hormones — the messengers — are objects of intense study on the part of the biochemist and the physiological chemist. The reward is great. Many human ills are due to deficiencies in metabolism, just as others may be traced to deficiency in nutrition. To what extent are these metabolic ailments due either to the lack of hormones or their failure to function properly? What is the chemistry of their action? What is the function of the many ductless glands, chemically speaking? Answers to such questions will mean advances in the application of chemistry through medicine, which may easily surpass those that have been made with the help of insulin,

one of the first recruits in this type of warfare upon disease. It may even become possible profoundly to influence mental and physical growth or to predetermine sex, a power requiring such wisdom in application as to make it dangerous.

The use of apparatus usually identified with some other branch of science for the work in hand is another encouraging sign in modern research. Consider what the adaptation of electrical devices has meant to chemistry, and how the microscope in its various forms is giving us a new system of analysis, both qualitative and quantitative, destined to become a most important method. The determination of constants is so necessary, in the case of compounds, that any method enabling such work to be done with accuracy on minute samples at once takes a place in the front rank of the tools with which we carry on our work. One unfamiliar with the possibilities of microanalysis and in the habit of requiring substantial quantities of an unknown for examination, finds it difficult to appreciate at first what minute samples can be made to yield reliable results.

Another broad field in which we find applied any device promising useful service is that of testing materials. Many look upon this as routine, whereas the development of testing methods calls for research of a high order. X-rays to detect faults in rolled, cast, or forged metal, motion photomicrography in ascertaining to what extent metal in service has become fatigued, and the problem of thorough testing without destruction of the sample, as well as the possibility of testing structural members in place, are examples of what is involved. A realization of the limits upon research imposed by apparatus has brought many important contributions from men gifted in this specialty. It will be recalled that Abbé, in appealing for new optical glasses, called attention to the arrested state of developement in science and industry, awaiting instruments impossible to construct without new types of lenses. The great impetus given to microscopy, astronomy, photography, and applied optics, when the new glasses became available, is a matter of history, and much that has been accomplished in

chemistry, medicine, physics, and other natural sciences could not have been done but for this work, which began to bear fruit in the early nineties. No less does research in chemistry depend in a large measure upon the glass, porcelain, alloys, and optical glass available to-day. We are beginning to use the motion picture as a piece of laboratory apparatus, and occasionally new substances are devised which extend the possibilities of our work. The synthetic resins, liquefied gases, and refractories composed of materials made in the electric furnace rather than by nature's tedious process are examples. When materials difficult to produce, even in small quantities, suddenly become available in sizes and shapes useful in laboratory procedure, new fields are at once opened. Thus the appearance within the last year of clear fused quartz in rods, discs, sheets, and other large masses may be expected to lead to new discoveries with the aid of the telescope, the microscope, and in the treatment of disease.

Chemistry is a useful science and has performed its share of the work throughout our scientific and material progress. Chemistry began by taking apart or dissecting substances of nature, that we might know with what we have to deal. Then came a period of stimulation when science was applied to increase yields, as in agriculture, and this application must continue. Now, having worked out many theories, we are in an age of structural chemistry, where we are concerned principally with synthesis and the conservation of natural resources through their efficient utilization. Chemistry, while continuing to offer the utmost attractions to the researcher, the philosopher, and the dreamer, is at the same time a science at work. As industry after industry becomes convinced that chemistry can be made helpful to it, more and more demands are made upon research, for there are still too many questions that cannot be answered from the data in hand nor by the work in progress. It is common knowledge among chemists that it is a simple matter to make rapid progress in an industry where chemists have had no previous opportunity, because widely known

principles may be applied to advantage where empirical methods have previously held sway. But the time soon comes when experience is insufficient, when new relationships must be understood and new data obtained before progress can be continued. The man who applies himself to fundamental work need have no fear that his results will not be useful. There is need for all the truth we can know. The danger is more likely to come from imperfect accounts of what has been done, of why and how it was undertaken, and lack of a clear statement of the facts established and their relation to other known facts. It is often surprising to find how careful an investigator has been in his work upon carelessly chosen material, and how greatly the value of the results could have been increased had the history of the sample been clearly established.

The pooling of resources upon research problems of major importance is one of our most encouraging signs. With some forty trade associations supporting research on a scale ranging from a research fellow or two to the maintenance of association laboratories, we may properly expect big things. This work, sustained in truly American fashion without recourse to governmental funds, nevertheless enjoys coöperation with the many splendid bureaus of federal, state, and municipal governments. If such trade association activity does no more than dispel the myth which surrounds most trade secrets, we will gain much.

When certain industrial concerns undertook investigations in pure science on their own account, another important step was taken in research. This has been followed by an interchange of the by-products of industrial research, a willingness to state problems of interest, and coöperation between the industries and universities that is full of possibilities.

We find, then, an increasing number of trained men and women in that type of research known as pure science or fundamental work. It is usually undertaken without thought of immediate application and primarily that bits of truth may be established. The trend of research here is toward establishing

the constitution of matter, the mechanics of the molecule, the structure of the atom, and the laws to which surface phenomena conform. A great number of relationships between elements and compounds under a wide variety of conditions are being established, and the products as well as the by-products of this research are being put to work in the industries.

Another group of equal ability is busy applying known facts to industry. This work is equally difficult and important. So far as the general public is concerned, the results are of more immediate interest and can be understood and better appreciated. But no one should forget that the foundations rest on some two hundred years of accumulated knowledge and established facts. This industrial research is truly a service activity. Whatever it may mean to its employer of the moment, it can nearly always be discussed in terms of economics and in some type of saving to the consuming public. No attempt will be made here to instance all the important trends in such research. A few examples will suffice to show how we are gradually but surely getting out of old ruts, revising our methods, and steering a course that seems certain to enable us to reach our objective.

For many years conservation of natural resources has been preached, and it is not surprising that with a seemingly inexhaustible supply the warning has fallen for the most part on deaf ears. To-day we begin to feel the pinch, not merely because we have increased our demands, but because the costs of transportation, manufacture, and distribution have risen so rapidly that, even where abundant raw materials are concerned, their influence upon the ultimate price of a given article is small. In other words, while a given structural steel member may cost somewhat more to manufacture than a few years ago, it costs much more to transport it, and a great deal more to place it than formerly. The replacement of such a structural member is therefore far more serious than was once the case. When the plumbing in your house fails, it is not the cost of the new pipe that bankrupts you; it is the cost of putting it

in place. We therefore seek means for prolonging the service life of materials. The corrosion problem in consequence is beginning to receive real scientific attention. The methods employed until lately to determine materials best suited for a given purpose have not been useful in disclosing the underlying causes of corrosion. Until we know whether it is due to some form of electrolysis or how to provide a self-healing film, we cannot expect the utmost success in producing non-corrosive metals and alloys that will make unnecessary the annual replacement of metals estimated to cost about three hundred millions of dollars.

Similarly, the whole field of protective coatings offers an opportunity for research that has seemingly not been widely realized. The electroplaters' art is still founded to a large degree upon empirical methods and formulas, but a few men of ability have applied themselves to these questions and have developed approved methods based upon their scientific data which have demonstrated their utility. It seems strange that those concerned with paints and varnishes have failed to take into adequate consideration the differences in the various woods to be coated, for until recently practically the same procedure and the same materials have been thought applicable to all kinds of woods. The men who know woods but not paints and those who know paints but not woods are beginning to labor together, and ultimately we should know the best treatment under all circumstances to give us better and more enduring coatings in accordance with the requirements of service.

But all our losses are not due to rusting or rotting. Marine structures, for example, have for many years been the subject of attack of borers such as the Teredo, reponsible for extensive damage often inflicted in a single season. What promises to be one of the most useful peace-time contributions of the Chemical Warfare Service lies in this direction. The application to marine piling of toxic compounds discovered in the course of research pertaining to national defense has given, according to experiments extending over many months, the first real promise

of coping with these destructive little mollusks that has come to us in several years.

In insecticides and fungicides, research is directed toward a more thorough application of the poisons used, as in the treatment of citrus trees under tents with hydrocyanic gas, and in the dusting of cotton with calcium arsenate, with the material in such a physical condition that a thorough covering of all parts of the plant is obtained. Another objective is to secure such adherence of poisonous dusts and sprays to the plant as to obviate the present necessity of repeated expensive applications. The secret in this appears to be the preparation of the insecticide or fungicide with an electric charge upon the particle opposite to that possessed by the green leaf. It has been done in the case of lead arsenate, the resulting material adhering to leaves under the most adverse weather conditions. Dusting with calcium arsenate by means of the airplane indicates that the particles discharged by the mechanism provided for the purpose are endowed with a positive charge, which attracts and holds them to the negatively charged leaf. Since the dusting of cotton has usually been confined to the earliest hours of the morning when the dew may cause adherence of the dust, and frequent rains sometimes render the expensive dusting useless, it is obvious that a dust that could be applied at any time, preferably by day when the thoroughness of the operation could be easily observed, and adhere to the plant regardless of the weather, would tend to increase the use of the only means which so far seems likely to decrease losses due to the weevil.

Coupled with this problem is that of forest protection against various moths and blights, which have already laid a heavy hand upon New England, Pennsylvania, and other parts of the country. The possibility of an annual dusting of large forest areas with a material that would adequately cover and adhere to all vegetation, although initially expensive, might easily prove so effective as to constitute one of the wisest investments possible.

Another important trend of our modern research is the pro-

tection, or rather preservation, of our harvested crops. Little understood fungi and plant diseases sometimes destroy 75 per cent of the sweet potato crop between the harvest and the table. The potato scab is a destructive agency in the white or Irish potato industry, and the part played by the Hessian fly and rusts in determining the price of our wheat is important. Many other instances might be mentioned, but it seems clear that, if these annual losses are to be avoided, it will be due to the efforts of the chemist in coöperation with the agronomist, the phytopathologist, and the entomologist.

A demand once established becomes restive under restrictions. America has become the greatest silk-using nation. Her raw material is all imported. The conditions of its production are uncertain, and wide fluctuations in the price of raw silk become a nightmare to silk manufacturers, who must contract to deliver months in advance. The statistics on the production of artificial silk are most interesting and show an expansion of the trade which has made possible the sale of nearly all varieties and grades of artificial silk thus far offered. Important steps in the production of artificial silk are still empirical. The goal of artificial silk manufacturers is the production of a fiber of greater strength and the ability to spin silk sufficiently fine for the sheer fabrics now in vogue. While both these objects may be accomplished ultimately by the use of sizing and finishing materials, it is evident that production will never be upon the soundest basis possible until more is known of the structure of the cellulose molecule. With this knowledge the manufacture of artificial silk could be made a science, and the demand for natural silk would decrease to the point where price fluctuations over wide ranges would be rare indeed. The difficulty of satisfactorily dyeing silks of the cellulose acetate class has limited the use of this material, which possesses certain superior characteristics; but that obstacle has been practically overcome and continued research in the field may be expected soon to remove all objections.

Another observation may be made on the trend of research in

this industry. There is a possibility that with such improvements as may be expected when the cellulose molecule is understood, serious consideration must be given artificial silk as an ultimate competitor of cotton. Already the cost of materials for the production of one pound of this silk is no greater than the cost of the raw cotton fiber. The silk is ready for weaving. The cotton must still undergo many processes before it can go into fine cloth. The spread between the two operations is therefore not great, and artificial silk has not seriously interfered with cotton thus far because it enjoys an insistent demand at a much higher price. How long cotton will continue as king may be determined in the chemical laboratory.

Nature has become somewhat uncertain in its supply of fossil gums, and we look to synthetic resin and ester gums to take their place. That this has already happened to a large extent is indicated by the satisfactory growth of these commercial enterprises. Indeed, protective coatings made from such resins and from nitrocellulose now offer the most active competition in the paint and varnish industry, and some forms threaten to supersede the older coatings within a very short time. The men engaged in this research strive to provide coatings with better anchorage, greater elasticity to withstand the changes due to temperature and moisture, to resist the abrasion of wind and dust, and to be inactive to the various cleansing agents and foreign substances with which they come in contact. It is again a case of economy and conservation.

In several industries of great importance to the public, development awaits the perfection of materials used in relatively small quantities. For example, the economic distribution of electric power depends, among other things, upon insulating materials. An increase in transmission voltage required for distribution over large areas makes it more difficult to keep the energy on the lines. It has a great tendency to leak and follows any course offered into waste channels. The electrical engineer calls to his assistance the chemist and the ceramist, who have together provided insulators which have made possi-

ble such transmission as we have, and which will ultimately be a vital factor in superpower lines. The chemist who has devoted himself to insulating materials involving gums, waxes, rubber, and the like, has contributed enormously to the transmission of power and to the perfection of communicating systems. Insulating varnishes also present a continuing problem in research, for they must satisfy the most rigid specifications, one of which is high efficiency at elevated temperatures. It is doubtful whether progress will be made in some types of electrical machinery until such varnishes can be made to withstand higher temperatures than can those now available.

It is also important to carry within a single cable as many telephone wires as possible, and the success in providing special papers for insulation, alloys of greater transmission ability, and cables to withstand adverse conditions of moisture and corrosion has kept our cost of communication within its present figure.

In places where nature may become exhausted, we naturally find some of the greatest rewards for modern research, and some of our most capable scientists hard at work. We are frequently reminded of the part cracking processes have played in enabling our petroleum resources to meet the ever-increasing demands upon them. Scientists believe that what has been accomplished is but the beginning of possibilities. Too few men of ability have been employed upon the chemistry of petroleum, and until crude oil can be converted into fluids suitable for internal combustion motors to the extent of 100 per cent, this problem cannot be included under the heading of finished business. Even when that has taken place, there may still confront this group of scientists the task of converting coal and other solid fuels, by hydrogenation or other means, into the more useful liquid form.

The appalling waste characterizing our use of the forests, the extent to which we have become a paper civilization, and the apparently sudden realization that we are using our timber four times as fast as new supplies are being produced, serve to direct research in dendrochemistry toward the perfection of processes

for using woods heretofore considered unsuited for pulp, and the search for new paper-making materials. Reference has been made to what has been done in the preparation of cotton linters for paper stock, and some recently announced work indicates that some woods which have been believed unsuited will make a satisfactory grade of paper for the less important uses. Ways must be found for using such short-fibered pulp as can be produced from cereal straws with wood fibers, and in time we may come to be very strict in allowing certain grades of paper to be used for purposes that are obviously of temporary value. The research that can open up new sources of useful fiber will be largely rewarded.

In pointing out that research on the utilization of low-grade ores is of great value we are not unmindful of what has been done in this direction. Succeeding generations, however, will be required to discover large ore bodies not now known or to work deposits that we now look upon as unprofitable. The success of those concerned with the use of oxygen in metallurgical processes may contribute important information to this problem. But when we remember that in the last two generations, if indeed not in our own generation, more metal has been used than in all previous history, the emphasis to be placed upon the purpose of research in the utilization of low-grade ores will be justified.

Our increased knowledge of the chemistry of colloids has suggested the possibilities in the handling of some raw materials, such as rubber, to preserve original characteristics and insure homogeneity of quality. To learn the constituent compounds liable to decomposition and how to preserve them has resulted, in the case of rubber, in a new material, latex, preserved in ammonia, applicable in many industries. Judging by the progress made when a new structural material is found or when a substance suddenly passes from a museum curiosity to an article of commerce, we may expect great things from research in such directions.

Transportation is giving rise to increasingly difficult problems.

The acquisition of a cushion rubber-tired phaeton was an event twenty-five years ago. To-day we easily distinguish between the exhaust of the automobile and the airplane, but scarcely look up while the modern marvel in transportation flies over us. We are even promised air-taxis at twenty cents per mile in the near future, and to-day balloon fabrics are rapidly becoming as important as steel rails. We are inclined to smile at the worries of those early Englishmen who anxiously regarded the disappearance of the yew tree, because it was considered the only satisfactory source of wood for long bows and without long bows England might be defenseless. Later, other Englishmen felt certain that the requirements of the English navy would surely exhaust the oak suitable for the construction of ships' knees. Still later, another group worried because the threatened charcoal shortage might limit the production of iron for national defense. To-day, the world looks with some jealousy upon the American supply of helium. Light, strong alloys, balloon fabrics that are elastic, inert chemically, and impermeable, problems of gas purification, the condensation of moisture from the exhaust of internal combustion motors to compensate the loss of weight with fuel consumption and so conserve gas, and a host of like questions crowd in upon those who conduct research in chemistry, physics, and the several branches of applied science which we designate as engineering. To increase safety, ease of handling, lifting power, speed, radius of operation are purposes for which such research is being conducted. Transportation in the air is a problem that really should concern us as individuals and the proper support of an air program by the Government would go a long way toward bringing commercial aviation in the very near future.

Similarly, new problems in food production are upon us. It may not occur in our day, but research in progress will doubtless make it possible, when necessary, to designate certain areas in which given crops are to be produced. Such areas can be designated when we know more of soil physics and soil chemistry, the relation of soil acidity, and particularly the true

physiological salt requirements of plants. Our knowledge of fertilizers has been principally about nitrogen, phosphorus, and potassium, and we are just beginning to know how important even minute traces of other elements may be to satisfactory plant growth. Some one has discovered that among other reasons for the success of Kentucky race horses is the fact that the blue grass enables these horses to maintain a satisfactory calcium balance, and along with our problems of human nutrition we must study those of animal nutrition, so long as we use the farm animal as a converter of roughage into forms of energy which we can use. We must develop ways for feeding to animals only such foods as the human being cannot digest. *Via* hogs we utilize only 16% of the energy in corn. Satisfactory progress in the fixation of atmospheric nitrogen gives reason to believe that there will not be the once threatened nitrate starvation, as predicted by Sir William Crookes several years ago, but we know little of the nitrogen cycle and have a great deal to accomplish before we can imitate the legumes which fix nitrogen at atmospheric temperatures and pressures without any commotion. It is no lack of appreciation of what has been accomplished in this difficult field of catalysis to point out how necessary it is to learn to work at lower pressures and lower temperatures and to find still better and more economical ways for the preparation of the gases required.

That new sources for such essential foods as carbohydrates are to be expected as a result of the present trend of research is indicated by at least two successful experiments. After many years of research a dry, granular dextrose has now been made available in commercial quantities. Recent announcements indicate that levulose produced from the inulin occurring in the mammoth French white Jerusalem artichoke and the dahlia may some day replace sucrose from the cane and beet. It is too early to predict how far this work may lead us, but experiments on a large scale indicate commercial possibilities of no mean order. No one is ready to predict that the laboratory will actually replace natural products for the production of our foods,

but this must not be listed among the impossibilities. If research now in progress succeeds in showing how to build up nitrogen-bearing compounds from simple materials, or carbohydrates from carbon dioxide and water, there is always the possibility of producing such substances on a commercial basis, particularly when we remember the low efficiency with which plants are shown to utilize solar energy.

Synthesis offers the greatest possibilities, which increase in geometrical ratio as we learn more about the molecule and the atom. At the moment the synthesis of naturally occurring compounds occupies many research groups, more especially where those compounds as they occur in nature lack uniformity in quality and are found far removed from the point at which they are needed, or occur in such forms as to render separation and purification an expensive undertaking. It has been demonstrated that, following the identification and isolation of active principles, the possibilities of synthesizing the material itself are greatly increased, and the series of investigations looking to such accomplishments come first in the activities of many laboratories. It has been said that chemistry has progressed from the blackboard to a structural science, which means that carefully worked out theories are beginning to bear important fruit, and especially so in industries where synthesis is properly evaluated.

We are naturally impressed with opportunities in the field of chemicotherapy. It is not enough to prepare in dependable pure form a known concentration of active principles of naturally occurring compounds. However important this work, it is surpassed by compounds built up for a particular application and with the needs of the physician specified. Efforts to introduce arsenic and mercury into the human body to destroy invaders without upsetting the delicately balanced mechanism of the human system have been largely successful. Such substances are molecules made to order. A special fat has been prepared for use where natural fats give objectionable products on degestion. Certain types of diseases have been overcome or

restricted with the aid of compounds made in the laboratory, and there is reason to believe that a continuation of this research in synthesis offers the greatest hope to the race in its efforts for longevity, and particularly an increase in that period of life which may be described as productive. At the moment, the chemical combination of metallic salts with bacteria, coupled with an antitoxin serum treatment, permits us to hope conservatively for victory over one of the few remaining diseases that scourge the race.

The trend and purpose of modern research, therefore, is to obtain that intimate acquaintance with nature that will permit continued progress in so changing materials as to render them more serviceable to our needs as they have developed throughout the years. If we are to enjoy a longer, safer, and more satisfactory type of existence with the minimum of disease, famine, and drudgery, we must look to a wider application of science and more adequate support of the fundamental research upon which the applications of scientific principles depend. We must also impress upon the public at large the truth of Pasteur's statement:

"In our century science is the soul of the prosperity of nations and the living source of all progress. Undoubtedly the tiring daily discussions of politics seem to be our guide. Empty appearances! What really leads us forward are a few scientific discoveries and their applications."

As our defenses are strengthened against those elements which strive to impede our progress, limit our development, raise barriers against and destroy us, may we be able to say as did the biblical historian, "So built we the wall."

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